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A decision model and data collection guide for planning change in material distribution systems

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A DECISION MODEL AND DATA COLLECTION GUIDE FOR PLANNING CHANGE IN MATERIAL DISTRIBUTION SYSTEMS

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THESIS

A DECISION MODEL AND DATA COLLECTION GUIDE
FOR PLANNING CHANGE IN
MATERIAL DISTRIBUTION SYSTEMS

by

George Richard Boyt

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Thesis Advisor: A. W. McMasters

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A DECISION MODEL AND DATA COLLECTION GUIDE FOR PLANNING CHANGE IN MATERIAL DISTRIBUTION SYSTEMS

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Technological advancements in materials handling systems and computer applications offer appealing solutions to the military material distribution system managers who are being forced to seek productivity improvements because of spiraling operating costs. However, these managers have little planning guidance and reference material to help them decide what to do. The purpose of this thesis is therefore to provide such help. A decision model is developed and suggestions are made for collecting data for use in the model. In addition, a summary of experiences of industry and military activities attempting to automate the materials handling functions is presented.

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I. INTRODUCTION

Over the period 1966 to 1977, output per man-hour has grown about 20.7% while labor rates have better than doubled [1: 16-20 and 2: 150]. The end result has been a decline in buying power of a dollar by 49% [3: 4]. What does this mean to the Department of Defense (DOD) logistics manager? In light of the fact that man-power costs for fiscal year 1977 accounted for 55% of the DOD budget, it means that he will have to strive to improve productivity through less labor intensive systems [4: 29].

Cost is not the only major problem facing the military logistics manager. As technology provides more sophisticated and complex weaponry, he is faced with an increasing range of items that he must stock to support these systems. Also and typical for a peacetime defense activity, governmental direction has resulted in reduction of manning levels within the defense establishment, both military and civilian. In many cases, the workload has remained unchanged or has not paralleled the declining labor force. There has been no relaxation or reduction in response requirements and required levels of effectiveness to compensate for the lost labor force. The end result is a paradox in that the military logistics manager is being asked to do more with less.

A. BACKGROUND

The problem of spiraling costs not being offset adequately by increased productivity is not unique to the Department of Defense and the Government. Industry is faced with the same problem in its pursuit of profits. Their profits are dependent upon maintenance of an adequate profit margin, which is the positive difference between what they can sell their finished product for and what it costs them to make it. If the market will not bear a higher finished product cost and production costs are rising, the profit margin will erode until the endeavor is no longer profitable. The only salvation for the industrial planners and managers in this situation is increased productivity.

This problem has helped support and sustain technolgical advancements in virtually every area of industry and government alike. Modern manufacturing processes, management information processing systems and human resources development programs are just a few of the areas that have been developed and expanded in the search for higher rates of productivity. Great advancements in productivity have been attributed to use of computers. But simple organizational or process changes have also contributed to improved productivity. Improved productivity may be difficult to obtain, but it is not an impossible goal in most cases.

The managers of military logistics systems have been aware of productivity problems and have been working on them at most military facilities throughout the country. Their

greatest success has come in the area of mechanization and automation of labor intensive functions because, as previously indicated, this is where a significant portion of the cost is incurred.

The military material distribution systems have been typcially labor intensive areas, because technology had not advanced to the state where such functions as sorting, order-picking, storage, packing, materials handling and information/documentation preparation and processing could be mechanized or automated. With recent technological advancements in computer technology and the development of mini-computers, micro-processors and programmable controllers, private industry has been able to relieve a significant portion of the human effort employed in material distribution systems. The new computer controlled systems and equipments are referred to as "smart equipments" because they can be programmed to accomplish a multitude of tasks and can communicate their activities within the computer control system. The net effect of this technological advancement is that the military logistician has a new alternative which he can employ to increase productivity.

Current military activity in procurement of automated materials handling and storage systems attests to the increasing use of this alternative. Appendix A is a listing of some large material distribution centers that have made or are in the process of making major capital investments on productivity improvement projects. Costs of these programs range from $4,000,000 to an estimated $41,000,000 per

installation [5]. The estimated total project cost for the Automated Storage, Kitting and Retrieval Systems (ASKARS) is estimated in the neighborhood of $124,000,000 [5].

B. THE PROBLEM OF SELECTING A NEW SYSTEM

Planning change in a material distribution system is a complex task. The problem solver may have to search through mountains of data and information to identify the relevant variables that are causing the need for change. Once he has defined his problem, he must develop alternative solutions and then evaluate them in order to select the best. The generation of alternatives has been complicated by technological advancements that have provided a multitude of equipment and services previously unheard of.

Where does the problem solver begin and how does he know what to look for? Technical industry planning and engineering publications are usually too detailed and complex for most problem solvers, industry sales literature is biased toward the manufacturer's equipments as solutions and there are few military planning publications that address this specific problem.

Because of the high costs associated with such productivity improvement projects, there is a definite need for a general planning guide and decision model for planning change in a material distribution system. The objectives of this thesis are to develop such a guide for data collection, recommend some techniques for data display and

analyses, and provide a simple general decision model for decision making in a material distribution system environment.

C. SCOPE

The scope of this thesis will cover the adaptation of a general decision making model to a material distribution system environment. As each step in the decision model is identified and expanded, sources of input data will be identified and recommended, techniques for analysis and collection of data will be provided and, where possible, evaluation criteria will be noted. While it is not possible to identify, quantify and qualify all items that must be considered in the decision making process, the decision model provided herein will attempt to address the most significant items and to stress the major concepts that have been proven over time to be most useful.

Throughout their experiences in implementing productivity improvement projects and changes in material distribution systems, industry and military managers have identified a number of major areas of consideration that have been frequently overlooked and have consistently resulted in major problems. These considerations will be briefly described and discussed so as to alert future systems planners of potential pitfalls.

The research effort to support the text of this thesis consisted of: (1) searching technical and trade journals

for information on productivity improvement in materials distribution systems, (2) solicitation of manufacturers for system literature and technical data, (3) visits to major military material distribution centers, (4) visits to major material distribution system equipment manufacturers, (5) interview with top managers of major material distribution systems and (6) telephone interviews with selected manufacturers' representatives. Additional literature was collected from various libraries and publications.

II. PLANNING CHANGE IN A MATERIAL DISTRIBUTION SYSTEM

"By applying automation to a problem without adequate planning or study, industry management achieves at best, a partial solution [6]." The theme of this comment has been echoed repeatedly by top management of the Automated Storage and Retrieval System industry's leading manufacturers [7, 8 and 9]. The same principle applies to any problem solving situation in a material distribution system. This is particularly true if the change significantly alters the relationship between interacting functions within the system. As such, a minor change in the system could have far reaching and undesirable consequences if the planning effort failed to incorporate complete analysis of the proposed change.

Any signficant change in the operations of a material distribution system, whether driven by a problem or a desire to modernize, is a complex undertaking. In either case, such an assignment can be accomplished by employing a general decision making model as the primary planning tool after it has been adapted to the material distribution system environment.

Ross A. Webber has developed a very simple model for rational decision making that will be used in this thesis as a starting point in the development of a model for planning change in a material distribution system.

WEBBER'S RATIONAL DECISION MAKING MODEL [10: 4]

1. Perception of the Problem
2. Diagnosis
3. Definition of the Problem
4. Generation of Solutions
5. Selection of a Solution
6. Implementation

R. A. Webber's model is ideal in that it takes an analytical approach to problem solving assuming a cause-effect relationship. The advantage to this approach is that the model user attempts to define the problem from causes identified through analysis of all effects. All too frequently, according to R. A. Webber and Norman R. F. Maier, the problem solver confuses the problem with one of its many causes and ends up solving the wrong problem [10: 26-27 and 11: 62-65].

R. A. Webber's model asks the problem solver to seek alternative solutions because, as Webber points out, managers and problem solvers are under pressure to act and are prone to accepting the first plausible alternative encountered [10: 25]. According to W. B. Semco, "80% of all materials handling systems are designed by in-house engineers," who often do a good job of optimizing the subsystems of a feasible solution, but they fail to consider other alternatives that could be better solutions [12: 78].

R. A. Webber's model is easily adaptable in that it can be expanded by inserting substeps between the primary steps.

These substeps can be designed to service the peculiarities of the problem or decision environment.

The model proposed here for use in planning change to a material distribution system follows:

A. PERCEPTION OF THE PROBLEM

1. Determine Objective(s) of the System

2. Determine Performance of Current System

3. Forecast of Future Operations and Changes

4. Identification of Differences

B. DIAGNOSIS

1. Analysis of Differences

2. Statement of Causes and Differences

C. DEFINITION OF THE PROBLEM

D. GENERATION OF SOLUTIONS

E. SELECTION OF SOLUTION

1. Testing

a. Physical Tests

(1) Physical Compatibility Test

(2) Performance Testing

b. Financial Tests

(1) Simple Cost-Benefit Test

(2) Payback Period Test

(3) Cost Effectiveness Test

(4) Break-even Analysis

2. Ranking

3. Other Considerations

4. Presentation of Alternatives and Recommendation

F. IMPLEMENTATION

1. Personnel

2. Planning and Management Tools

3. Acceptance Testing and Evaluation

A. PERCEPTION OF THE PROBLEM

The fact that a problem exists may or may not be evident to the prospective problem solver. His ability to perceive a problem is related to his knowledge of the operation and the immediate situation. The symptoms of a problem may range from not so obvious minor variances in production or financial reports to obvious stoppages of operations. Another not so obvious indication that a problem exists is a casual request by one's superiors that a change, modification or a plan be studied or considered for implementation. Regardless of the obviousness of the symptoms and the level of demand for action, a logical approach is needed to aid in the collection of data to properly diagnose the potential problem situation.

In his approach to problem solving in a materials handling system environment, James M. Apple cautions that one should employ the "systems concept" in his analysis. Essentially, what he has said is that the system is "a complex unity formed of many diverse parts, ...regularly interacting or interdependent, ...serving a common purpose [13: 276]." To say it more simply, a change that alters the interaction

or interdependence of the system's parts will result in a change to the system's final output.

One way to develop a logical approach to problem solving taking Apple's caution to heed is to approach the perceptual phase of the problem asking the following simple questions: (1) where is the system going, (2) where is the system now, (3) what other changes can be expected to affect the system, and (4) what are the differences?

1. Determine Objectives of the System

The determination of the objectives of the system answers the question of where the system managers want the system to go now. Typically, the objectives can be found in the functional or mission statement of the system or activity. The functional or mission statement will normally indicate the primary goals and objectives and provide an operational hierarchy of functional/task responsibility.

The purpose of reviewing and restating the system's objectives is to reinforce the idea of what the system is really trying to do on the overall level. All too often this step is left out of the planning function and the problem solver gets so inmeshed in the causes that he loses sight of the system's ultimate goals. The result is typically optimization of some function with an offsetting suboptimization of the total system.

Restating the system's objectives provides a second valuable service. It provides a base from which to evaluate current operations and a starting point from which strategic planning (long range) can commence.

2. Determine Performance of Current System

By determining the performance of the current system, the question of where the system is now can be answered. The significance of answering this question is that one can compare current performance to current plans and system objectives and determine if additional or different action is needed to move the system toward its objectives.

It is extremely important that current performance be accurately determined. If current performance is reported as being where it is believed to be or where one wants it to be instead of where it actually is, the task of aligning the system with its objectives may be significantly overstated or understated.

Determination of current performance is a demanding task, but it is not an impossible task. It basically involves a data collection and collation effort. The data collection task can be subdivided into three primary areas and attacked individually. The three areas are (1) Organization and Operational Process Review, (2) Collection of Operational Performance Statistics, and (3) Collection of Facilities and Equipment Statistics. Appendicies B, C, and D are provided as data collection guides.

a. Organization and Operational Process Review

Organization and operational process review is simply the task of reviewing the organization as it currently stands. Later the results of this review will be compared with the organization as it is depicted in the activity's

organization manual or chart. The operational process review consists of reviewing the function-task-activity relationships within the system's operations and later comparing them with the current operations plans. Appendix B provides two suggested methods that may be used to accomplish this task.

The first one, Organization Chart Method, relates functions, tasks and activities to the originally planned organizational structure and then to the organizational structure as found from a review. The second, Functional Method, consists of relating the activity's organizational elements to the functional (or process) structure of the activity as it was originally planned or designed and then as it was found from a review. Both methods accomplish the same objective, they just approach the problem from a different angle.

The objective of this review is to determine what changes actually have evolved within the organization and its operational processes. Unintended or unnoticed migration of a function, task or activity between organizational subelements could be one of several causes of a system problem.

b. Collection of Operational Performance Statistics

Collection of operational performance statistics is probably the most difficult task in the area of data collection. The information sought here is needed to identify the current operating environment. Much of this data is routinely being collected and can be found in work measurement

reports, financial and property accounting reports, activity management information system reports, method or production standards, operating instructions and special reports. Some data may not be available and might have to be sought through statistical sampling and surveys. It would not be unusual for the sampling and collection phase of this task alone to consume the better part of two to four months of labor for several people[8].

Once the data is collected, it must be processed into a usable form. Sections I, II and III of Appendix C are provided as a suggested guide to aid this phase of the data collection and processing effort. These sections identify the activity, its environment and list the most frequently used and more relevant operational and performance statistics needed for planning change in a material distribution system environment. Appendix D is a guide for identifying daily activity peak loading in critical tasks.

c. Collection of Facilities and Equipment Statistics

The task of collecting facilities and equipment statistics basically involves identifying all facilities and equipments employed in the system. It is essential that all equipment be included and that they be rated at their present production or process capacities. Original performance specifications and capacity ratings for a piece of equipment are irrelevant if something has changed within the equipment that affects its output capability. (Example: normal wear and tear may have significantly reduced some of

the equipment's capacity; equipment modification may have increased capacity, etc.)

The information provided through this task serves to identify the range and depth of the facilities, their related capacities and their applicable limitations. The problem solver in essence receives a summary of the existing physical resources that he has to work with. Equipment imbalance could be a possible cause of decreased or unsatisfactory productivity. Then too, if the ultimate decision maker decides to live with or make do with what he has, he will know exactly what his resources and capabilities are.

Sections IV and V of Appendix C provide a general outline of the equipment and cost information needed to complete this task.

3. <u>Forecast of Future Operations and Changes</u>

A forecast is an educated prediction of the occurrence of a future event or state of the environment. A realistic forecast can be useful to the decision maker in that it provides some insight into the future within some level of certainty. Therefore, a forecast of the future will help the system planner and problem solver answer the question of what changes they can expect within what timeframe. This information can provide the user with a relative indication of the value of timing with respect to commitment of resources. Within limits, the decision maker can perceive major changes in the environment or technology from the forecast. This information could encourage or

discourage decisions to invest in major capital projects within the planning timeframe.

The reliability and accuracy of a forecast is in a large part a function of its source. The most common sources of reliable forecasts are industrial organizations, governmental organizations and reputable consultants. Frequently, however, the organization must rely upon forecasts generated by its own staff. Relatively accurate forecasts can be prepared by capable in-house planners [15: ix-x].

Regardless of the source of the forecast, its use provides the added dimension of a dynamic solution--it looks for change in the future rather than expecting a static environment based on past history. This fact in itself is invaluable in that it reinforces the idea that whatever solution the problem solver chooses, it must be flexible and able to adapt the change.

Table 1 lists some of the more common and relevant forecasts employed in planning changes in a material distribution system. There are essentially two types of forecasts in this list, subjective and objective.

The subjective forecast is one that incorporates subjective factors within the forecast. In other words, it addresses qualitative considerations that will have a definite affect on the level of value of the forecast in the application time period. The factors or considerations are usually derived from generalized statements and observations and are not readily quantified by numbers, nor are they usually developed from a historical set of numerical data.

PLANNING FORECASTS FOR MATERIAL DISTRIBUTION SYSTEMS

1. Change in Mission or Strategy (Includes Organizational Changes)
2. Changes in Level of Operations
    a. Changes in Total Demand and System Throughput
    b. Changes in Range of Line Items
    c. Changes in Depth of Line Items
3. Change in Response Requirements
4. Change in Processes or Methods
5. Changes in Facilities or Equipment
6. Changes in Personnel Support Level
7. Changes in Variable Operating Costs

TABLE 1.

The Delphi Technique is one way that relatively accurate subjective forecasts can be generated. It is basically a method of generating a reliable consensus on a subjective prediction utilizing a panel of experts, a questionnaire and a sequence of rounds employing feedback and statistical analyses for the purpose of refining the group forecast [14: 25].

Some typical subjective forecasts would be mission or strategy changes forecasted from generalized statements on such things as energy conservation, pollution control, world politics, etc. The subjective forecasts in Table 1 are 1, 3, 4, 5 and 6.

The objective type of forecast projects the value of a time period by "casting forward" the past performance

or the historical data comprising the time series [15: 633]." Forecasting in this sense is the analysis and extrapolation of historical data to project the occurrence of a future event in an environment where there is little reason to expect any signficant change in the prior trends or patterns. There are a number of statistical forecasting tools that can be employed to develop this type of forecast. Chapter 21 of Reference 15 provides a brief description and formula for the more common ones: Moving Average Forecast, Exponential Smoothing Forecast, Sinusoidal Forecast and the Autoregressive Forecast.

A typical example of an objective type of forecast would be one that projects stability or change in an inventory using historical demand data. Forecasts 2 and 7 in Table 1 are this type of forecast.

The individual responsible for gathering data and preparing forecasts will quickly find that there are no ready references to help him with his data collection chore. Table 2 provides a list of suggested sources of input data by type of forecast.

Appendix C can be utilized as an outline guide for identifying needed forecasts and for incorporating forecast data into the overall plan. This can be done by expanding Appendix C through the addition of a column titled Forecasted Changes (See Appendix E). The problem solver can then go through a forecast. As these forecasts are completed, the forecast data can be entered next to the appropriate statistic or caption in the Forecasted Changes column.

SOURCES OF FORECAST DATA

Type of Forecast	Sources of Input Data
Predictive Forecast	1. Operating Directives and Policies
	2. Directives from Higher Authority
	3. Command Mission Statement
	4. Command Policy Statements
	5. Command Directives and Instructions
	6. Command Operating Plans
	7. Command Financial Plans and Budgets
	8. Command Facilities and Engineering Plans
	9. Technical Directives from Higher Authority
	10. Industry Publications
	11. Trade Journals
	12. Military Journals
Forecasting Forecasts	1. Work Measurement Reports
	2. Inventory Records
	3. Financial Records and Budgets
	4. Maintenance Records and Reports (Equipment)
	5. Maintenance Records and Reports (Facilities)
	6. Maintenance Plans and Programs
	7. Management Information System Reports
	8. Special Studies and Reports

TABLE 2.

4. Identification of Differences

The differences are nothing more than the changes needed to attain the system's goals and objectives. To identify the differences, the problem solver must incorporate the forecasted changes into the current system's capabilities to define the near-future system's environment or requirements. This only identifies where the system would go if it

were permitted to follow the forecasts, which may or may not coincide with management's desires. In light of this information, a review of the near-future system's environment must be conducted by the decision maker to either update or reaffirm prior objectives and goals in accordance with management's desires. At this point, the problem solver can begin identifying differences by comparing current capabilities to updated/reviewed goals and objectives.

This process is time-consuming but should not be difficult. The General Planning Data Sheet (See Appendix C) can be employed as an aid in this task. It would be expanded to read in five columns, current system's capabilities, followed by forecasted changes, then near-future system's environment/requirements, next updated goals and objectives and finally differences. Essentially, the planning data sheet has become a summary worksheet.

Given that current system's capabilities and forecasted changes were derived earlier in the process, the near-future system's environment is the next item of interest. It is either the forecast figure for the statistic if change was forecasted, or the current system's capability figure if no change was forecasted. The updated goals and objectives are the individual figures established and/or approved by management subsequent to the decision maker's review of the near-future environment/requirements. The differences are then the results from the subtraction of updated goals and objectives from the current system's

capabilities. Positive differences indicate excess capacity which should be reviewed for possible reduction and cost savings. Negative differences indicate a shortage of capacity and a need for expansion. Appendix E is a sample section of the modified General Planning Data Sheet which illustrates the process of determining the differences.

B. DIAGNOSIS

As previously indicated, the basic approach to problem diagnosis advocated herein is analyses of cause-effect relationships. The effects are essentially the differences identified on the General Planning Data Sheet (Summary Worksheet-Appendix E). The causes are identified through analyses of these differences. In this instance then, the cause is the relevant variable within the system that is contributing to the system's output in an undesirable way.

Once all of the cause-effect relationships are identified, the problem solver is in a position to accurately define the problem and assess its impact on the system. Accurate definition of the problem is essential to avoid mistaking a cause for the problem. Misidentification of the problem could lead to acceptance of an inadequate or inappropriate solution. It must be noted at this time, that there can be multiple causes of a problem. Likewise, a problem environment could include more than one problem with some commonality between causes.

1. Analysis of Differences

The analysis of differences consists of reducing each difference down to its most elementary parts and then studying the functions of each part and the relationship between parts. A systematic and logical approach to analysis is generally the most successful method of identifying and isolating causes. Although a cause of a difference may become evident early in the analysis, it is advisable to complete the analysis since valuable data may be overlooked that had not been revealed in the early stages of the analysis. This data is valuable in that it may reveal an important interacting relationship with another contributing cause and/or it may identify the level of influence that the cause has on the system.

2. Statement of Causes of Differences

After the analyses of all differences has been completed, the problem solver should have a list of causes and an associated list of differences. At this point the problem solver is advised to reduce each cause and each difference down to a very simple form, either a very short sentence or preferably a short phrase. The purpose of this reduction is to put each cause and each difference into a form that is easy to recognize and relate to. In other words, it is easier to compare the contents of a series of short phrases than it is to compare the contents of a series of paragraphs or multi-paragraph statements.

For purposes of clarity and in order to retain the relationships derived in the analysis, it is recommended

that the identified causes and differences be put into a tabular form. Each cause should be related to all of its various differences and a brief phrase should be included that reflects the impact of the difference on the system's objectives. Figure 1 provides a suggested format for displaying the information derived from the analyses.

FORMAT FOR DISPLAYING CUASES AND DIFFERENCES

Causes	Differences	Impact
I. Renegotiation of Union Labor Contract	1. Salary Increases by $800,000 per year	1. Higher Direct Labor Costs
	2. Increased Fringe Benefits by $320,000 per yr.	2. Higher Overhead Costs
	3. Lunch Room Habitability Project--$50,000	3. Higher Overhead Costs
	4. Additional Coffee Break 15 Minutes per Man	4. Decrease in Productive Work Hours
II. Old/Obsolete Equipment	1. Increased Material Waste $250,000 per yr.	1. Higher Direct Material Costs
	2. Declining Equipment Efficiency $300,000 per year	2. Higher Direct Labor Costs
	3. Rising Maintenance Costs $325,000 per yr.	3. Higher Overhead Costs
	4. Increasing Utilities Consumption $37,000 per year	4. Higher Overhead Costs
	5. High Quality Control Rejection Rate $275,000 per year	5. Higher Direct Material and Labor Costs
	6. Increasing Number of Work Stoppages 4 per yr. at $10,000 each	6. Higher Operating Costs
	7. Inflexibility in Production $500,000 per yr.	7. Lost Sales
	8. Declining Production Efficiency 2500 units per year	8. Declining Productivity
III. Increased Import Taxes on Raw Materials	1. Increasing Materials Costs $900,000 per yr.	1. Higher Direct Materials Costs
	2. Increasing Raw Materials Holding Cost $67,500 per year	2. Higher Overhead Costs

FIGURE 1.

Next, the problem solver should compare the list of causes and their associated lists of differences looking for repetition and/or duplication. For example, if two different causes have the same list of effects, it is highly probable that they are the same cause. In this case the problem solver may have inadvertantly defined the same cause using two different descriptive phrases thinking that he had identified two different causes.

C. DEFINITION OF THE PROBLEM

After the problem has been diagnosed, it needs to be stated or defined in clear and concise terms. One way to accomplish this and avoid a built-in bias in problem solving is to state the problem in terms of the system's objectives, rather than in terms of alternatives or solutions. The difficulty in stating the problem in these terms is directly related to the problem solver's perception of the system's objectives and his understanding of the relationships between the system's relevant variables, the causes and the differences. Throughout this process a trend or repetitive result will be disclosed. The trend or common result is likely to be the problem.

To illustrate this procedure, take Figure 1, for example, and put it in the context of a private manufacturing firm. Their primary objective would be to make a profit. Now by projecting the impact of each effect of the differences on the system, one can see that the predominant end result is a higher cost of operation and a secondary result of declining

productivity. This problem can be described in several ways, but one good definition would be for the primary problem, profit margin erosion, and for the secondary problem, declining productivity. In this case, both primary and secondary problems have been addressed and are clearly defined.

By structuring the problem statement properly, the problem solver can outline the objectives or basic tasks that the alternative solutions must accomplish to resolve the problem. Essentially all that this involves is stating the problem and listing the causes under it in descending order of relative effect on the system.

An illustration of this process is provided in Figure 2 employing the data from Figure 1. The ordering or ranking of causes is easy in this instance in that monetary costs are provided for each difference or can be computed for them. The most costly cause would be the most significant, and therefore would head the list.

If the costs of the various differences for each cause are not known and cannot be predicted within an acceptable level or accuracy, then another form of ranking is needed. In this instance one can apply utility theory through the Delphi technique and develop an acceptable ranking mechanism. For information on utility theory in ranking, refer to page 52.

SAMPLE PROBLEM STATEMENT

Primary Problem(s)	Causes	Impact on System
1. Profit Margin Erosion	1. Old/Obsolete Equipment	1. Annual Cost: \$1,727,000
	2. Renegotiation of Union Labor Contract	2. Annual Cost: \$1,170,000
	3. Increased Import Taxes on Raw Materials	3. Annual Cost: \$967,500
	Total Cost of Primary Problem:	\$3,864,500/year
Secondary Problems		
1. Declining Productivity	1. Old/Obsolete Equipment	1. Lost Production: 2500 units per yr.
	2. Renegotiation of Union Labor Contract	2. Lost Production: 2062.5 units per yr. (.25 hr/day x 220 day/yr x 75 men ÷ 2 labor hr/unit produced = 2062.5/yr)
	Total Cost of Secondary Problem:	\$71,859/year
	(2500 + 2062.5) x \$15.75 gross profit/unit = \$71,859	

FIGURE 2.

The advantage of the ordering or ranking of the causes under the problem(s) is that by resolving the most significant causes first, the lesser causes may be resolved or reduced to non-relevant variables through the spin-off effect. The results of this process could be a simpler and less involved solution.

D. GENERATION OF SOLUTIONS

A. T. Waidelich, Executive Vice President of Engineering and Research for the Austin Company, in discussing the systems concept approach to problem solving and recounting past industry problems in materials handling, cautions the reader on the "need to maintain an open mind in the search for Workable solutions [16: 4]." In support of this statement, both N. R. F. Maier and W. B. Semco reflect upon the fact that the first solution to a problem may not be the best in terms of overall objectives [11: 119, 12: 78 and 17: 278-283].

The search for alternatives should take into consideration the full range of possible solutions, from doing nothing, to making minor internal changes, to undertaking a productivity improvement plan or to resorting to mechanization or automation at various levels. Regardless of the problem solver's immediate reaction to or perception of an alternative, the alternative ought to be listed and evaluated in the same terms as all other alternatives. Surprisingly, an alternative not well received initially, may later be found to be a better or more cost-effective solution.

Frequently, the activity faced with the problem does not have the staff capability to generate, cost and evaluate a set of appropriate alternative solutions. In this situation, the activity might want to consider hiring a consulting firm to study the problem and provide a list of costed and evaluated alternatives. This service can be invaluable to an activity with limited engineering capability.

If a consultant is utilized, the consultant should be tasked with developing contract specifications where it is obvious that the alternative will be implemented through use of a contract. In such an instance the consultant should be required to develop the contract specification based on performance. Avoidance of hardware specific specifications should result in a wider range of contract solicitation responses and possibly better overall solutions.

Industry experience with problem solving in materials handling has leaned heavily toward mechanization and automation [18: 88-94]. Although this may be the industry trend, notable results have been achieved through the alternative of non-mechanization or non-automation. National Distillers has achieved documented annual savings in excess of $600,000 on an investment of $100,000 in a productivity improvement program without automation or extensive computerization [19: 55-56]. Essentially, National Distillers' productivity improvement program consisted of major procedural and control changes developed from a flow chart analysis of the organization and the operation.

Equipment is always an item for consideration in materials handling system problems. Various configurations and mixes of equipment frequently become alternative solutions to a problem. To aid in equipment selection in warehousing and materials handling situations, the Naval Supply Systems Command (NAVSUP) is currently in the process of updating an equipment selection and planning guide, NAVSUP Publication number 529, Warehouse Modernization and Layout Planning

Guide (See Appendix F for its table of contents and a brief description of the manual's organization). This is a detailed manual describing an array of common general materials handling equipments and automated storage devices and their applications. The general problem solving approach employed in the manual is the development of inventory modules. These modules are basically blocks of stock items with compatible physical characteristics (sizes, shapes, weights, etc.) and the same or similar turnover rates. The turnover rates are referred to as Transaction/Inventory Ratios (T/I Ratios) or the number of anticipated transactions per day for an item divided by the number of that item carried in the inventory. Each module is mechanized or automated by selecting equipment configuration modules on the basis of the standards and the decision matrices which compare costs with various requirements. The equipment configuration for each inventory module is then married into an integrated system solution taking into consideration module interfaces, operating and environmental constraints and costs.

E. SELECTION OF SOLUTION

Assuming that intuitively viable alternatives have been generated up to this point in the decision making or problem solving process, the relative level of success in solving the problem is now dependent upon the quality of the alternative selected. This is not to say that selection is the only key to success, because implementation of a decision or solution is equally important as will be discussed later. The

point to be stressed is that the results of a problem solving effort cannot be expected to be any better than the quality of the alternative selected.

Determination of the quality of an alternative requires that all known alternatives be evaluated against a common set of parameters and ranked as to which best meets these parameters. This process can be broken down into two phases: (1) testing and (2) ranking. The testing phase consists of determining the relative ability of the alternative to perform a prescribed series of standard (defined) tasks within a specified environment. The ranking process involves establishment of an order of preference based on an aggregation of test results and applicable nonparametric factors.

1. Testing

Testing must obviously precede ranking of alternatives if there is to be a sound basis for deriving order. The two typical types of tests are: (a) physical, and (b) financial. The physical tests determine if the alternative is physically compatible in the system or the problem environment, and they predict the relative physical effectiveness of the proposed alternative. The financial testing is essentially an economic analysis designed to determine the economic impact of the alternative.

a. Physical Tests

(1) Physical Compatibility Test. The physical compatibility test is simply a check to see that the proposed alternatives meet all constraints identified in the

data collection phase. Additional consideration should be given at this time to other characteristics of each alternative that may undesirably affect the system or an associated system's compatibility. Some examples of these types of tests or considerations can be found in Table 3.

PHYSICAL COMPATIBILITY TESTS

1. Is the proposed existing structure physically large enough to house the new proposed ASRS system?

2. Will the vibration generated by the new materials handling system affect the adjacent instrument calibration lab?

3. Is the pallet handling system proposed for use in the cold storage plant designed for operation in 0°F. or below temperatures?

4. Will the heat generated by the new proposed material handling system in the freezer plant create a refrigeration problem?

5. Are the utilities systems at the activity capable of supporting an increased load that would be applied by adding a new system or expanding an old one?

6. Is the facility floor structurally sound and capable of supporting the floor loading employed in the proposed new system?

TABLE 3.

Physical compatibility tests ought to be used to screen alternatives before further testing takes place.

Since virtually every facility or activity is unique and there are no pre-prepared lists of basic physical compatibility tests for all facilities and activities,

it is up to the problem solver to develop his own basic series of tests based on his knowledge of the current system.

Regardless of who conducts the physical compatibility tests, it is a very important yet an inexpensive task. Overlooking the need to test all alternatives for physical compatibility could be very embarrassing and costly.

(2) Performance Testing. Where possible, it is desirable to test the performance of alternatives in the environment where they would be utilized if selected. Frequently, especially with smaller equipments, it is possible to set up a pilot program or test bed where each alternative can be tested and evaluated based on actual performance. This approach to testing is the most desirable since it is the most accurate and reliable, and it ought to be employed whenever possible.

Another approach to evaluating alternatives involving small equipments is to seek out similar activities under consideration. Onsite visits and information from both management and work force will be useful. But one should be aware of the fact that he seeks documented and proven facts and statistics, not opinions or estimates.

Likely as not with large systems or integrated solutions, the problem solver will not be able to run a pilot program or find a comparable example to his problem. He is then left with two choices, accepting the design engineer's projections or resorting to a computer simulation of the system. Normally, the problem solver has no way of

checking the design engineer's work, so if he takes the computer simulation, he is not totally reliant upon a contractor's optimistic solution.

> A system simulation is a representation of the system in terms of its logical and mathematical rules. Simulation in one form or another has been used for years as a technique of evaluating system performance. There have been scale models, mathematical models, dynamic analogies, and a wide variety of techniques to represent continuous behavior of a system. In a General Purpose System Simulator (GPSS) simulation, the representation of the system--the rules and the relationship that describe it--are interpreted in computer language.
>
> Once the model has been developed and confidence has been established that a valid representation exists, then a series of parametric simulations can be run to gain understanding of the system behavior. The system designer gains insight in the operation of the system--while the system is still a paper concept [20].

Today, most manufacturers of modern materials handling systems, whether mechanized or automated, have computer programs which are capable of simulating and analyzing various equipments and materials handling systems. Mr. William McAfoose, a general manager for LITTON UHS indicates that computer simulation in systems design has proven to be invaluable in LITTON's development of large automated storage and retrieval systems [8].

The advantage to simulation, if the proper probability distributions are known for the planning data, is that the program can identify system design faults and weaknesses. Consequently these deficiencies can be eliminated before the actual system is installed. The cost of change is minimized if incurred in the system design phase.

Since most activities are not blessed with a large staff of computer programmers and analysts who are capable of developing a system simulator program, they must go to consultants who can provide this service or they may purchase this service from one of the major materials handling system manufacturers.

b. Financial Tests

The financial testing phase of the problem solving or decision making process is essentially an economic analysis of the alternatives. The objectives of the economic analysis as previously indicated, are to determine which of the alternatives are economically feasible and establish an order of economic preference among the alternatives. The economic feasibility questions is simply, does the total benefit gained from an alternative equal or exceed the total cost incurred by its implementation?

The process of economic analysis is described in Reference 16 and has been outlined in Appendix G. Regardless of how the economic analysis is done, costs and benefits must be identified and tabulated. Some firms and industries conduct their economic analyses utilizing only major costs and primary benefits and, as a consequence, obtain only rough economic indications of the relationships sought. But most major industries and governmental agencies are using economic analyses of the total system over its useful life. This process is called Life Cycle Costing--costing of the system from inception through disposal or abandonment. Essentially every cost item and every benefit are identified

throughout all phases of the life of the system and a value is computed or assigned wherever possible. Since personnel support/training and system's maintenance costs account for a major portion of the total life cycle cost of the system, they should be considered and incorporated in the cost portion of the analysis. A comparison can be made to determine if the value of the benefits exceeds the total cost and to establish a ranking of alternatives.

Looking at costs first, Benjamin Blanchard recommends that the analyst or problem solver develop a cost breakdown structure similar to a tree diagram, showing cost categories and how they contribute to the total cost [21: 316]. He further goes into cost categorization and development of system elements, but as he notes, there is no set method for cost breakdown. Appendix H provides an outline of some major cost items that should be considered in the various phases of a material distribution system's life.

As step four of Appendix G (page 105) indicates, some costs will be identified that can be quantified and possibly others will be identified that cannot be. Quantifiable costs can normally be identified or computed from known data with little difficulty. Non-quantifiable costs are difficult to cope with, but they should not be discarded nor should they be ignored. If the problem solver is unable to attain a subjective assessment from an expert or he cannot estimate the cost with some degree of confidence, then he should document the non-quantifiable cost and retain it for consideration during the final phase of evaluation, just

before the decision is made. The documentation need only consist of a brief written statement describing the non-quantifiable cost and identifying what its impact is expected to be. At the time the decision is made, the decision maker will have to subjectively incorporate the cost into his decision.

Like costs, all benefits should be identified and a value assigned to those that are quantifiable. Similar to non-quantifiable costs, non-quantifiable benefits should be documented and retained for consideration just prior to making the decision.

A sample format for displaying and comparing benefits has been extracted from Reference 16 and is provided as Figure 3. The various benèfits that would be listed in this format would be those identified during the analysis.

BENEFITS WORKSHEET

Benefits	Mode of Appraisal (Whether or Not Quantified)	Alt. I				Alt. II				Alt. III
		Years of Alternative Life				Years of Alternative Life				Etc.
		1	2	3	4	1	2	3	4	
1. Production	Items per hour									
2. Customer Satisfaction	% served on time									
3. Safety	# of Accidents per employee									
4. Morale	Narrative and/or ranking (reaction of community to system planned) Good (1), Poor (2) Indifferent (3)									
5. Quality	Errors per record									

FIGURE 3.

In situations resulting in a stream of costs and benefits over a long period of time, the time value of money must be considered. "The government must determine the approximate value of the money it spends from the private sector's savings, since those savings would earn interest at some rate if not spent by the government [16: 15]." The government has recognized the private sector's "lost opportunity" by establishing a discount rate of 10% which represents its cost of money [22]. Therefore, when considering a stream of costs and benefits, Department of Defense activities must discount their investments to present value using a 10% discount rate.

Once all costs and benefits have been identified, valued and discounted, the problem solver or decision maker is in a position to commence testing and ranking of alternatives. There are many economic tests that can be employed in this process, but only a few of the more common ones will be described here. The problem solver or decision maker can decide from his experience and the information that he has gathered thus far, which tests should be applied. The testing and ranking process equates to steps five and six of Appendix G (page 105).

The common tests that will be described here are a simple cost-benefit test, a payback period test, a cost effectiveness test and a break-even analysis.

(1) <u>Simple Cost-Benefit Test</u>. The economic feasibility of an alternative is determined through use of

a simple cost-benefit test. It simply involves comparing the total discounted value of benefits derived from an alternative to its total discounted costs. If the value of the benefits exceeds the value of the costs, then the alternative is economically feasible. In other words, the value of the services gained or the amount of savings incurred over the economic life of the alternative is expected to equal or exceed the value of its costs before it is considered to be a feasible alternative.

(2) Payback Period Test. The payback period test is essentially only a modification of the simple cost-benefit test. Its only real difference is that it tells the problem solver when the discounted costs equal the discounted benefits with respect to time. This test is most easily described through use of a graph. The horizontal axis represents the life span of the alternative (time) and the vertical axis represents dollars. First, the problem solver identifies the fixed cost (procurement or capital investment) and draws a horizontal line across the graph at the cost level equal to the fixed cost (fixed cost line). Then he plots the discounted annual savings or net benefit value of services received at each annual increment along the horizontal axis (benefit line). At the point where the benefit line intercepts the fixed cost line, a vertical line is then dropped to the horizontal axis and this identifies the expected length of time until the alternative pays for itself--payback period. The discounted annual savings or

net benefit of services received is found by subtracting the discounted value of annual variable costs from the discounted value of total benefits received for that period.

An example of this would be that, if an automated conveyer system was being considered that had (1) an expected life of ten years, (2) a capital investment cost of $1,500,000, (3) a zero salvage value after ten years, and (4) estimated annual net benefits of $205,000 for the first three years, $165,000 for the next three years, $130,000 for the following three years and a $100,000 for the last year, the estimated payback period can be found to be nine years (See Figure 4).

PAYBACK PERIOD TEST

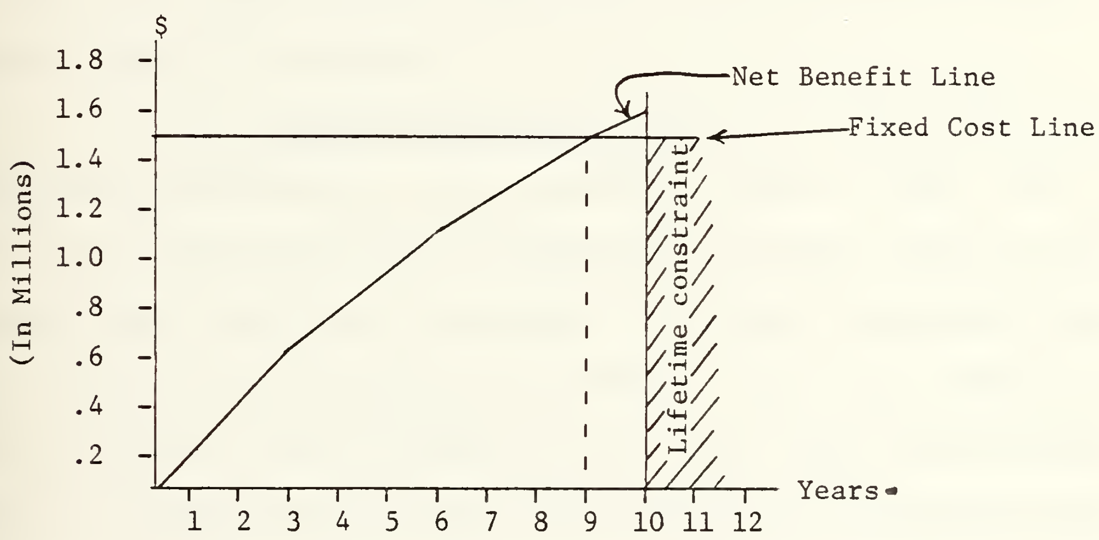


FIGURE 4.

The value of this test is that it checks to see if the alternative will pay for itself, first within its expected lifetime and second within any externally applied

constraint, such as a command policy that would require the alternative to pay for itself within a specified timeframe.

Both the simple cost-benefit and payback period tests provide the decision maker with pass-fail answers. Either they are economically feasible and they pay themselves back within the prescribed timeframes or they don't. These two tests have value in ranking of alternatives, too. Relative comparisons can be made and ordered on the basis of differences in amounts saved per dollar invested and on shorter payback periods.

There are two common financial tests that provide primarily ranking data; the cost-effectiveness test and the break-even analysis. They provide information that is useful in comparing and ordering of preference of alternatives based on economics.

(3) Cost-Effectiveness Test. The cost-effectiveness test is basically a ratio employed where a basic unit of measurable output activity is identified and is common among alternatives. The ratio is simply the total discounted life cycle cost of the alternative divided by the total number of units produced in the system's life. This test can be modified by incrementing the cost and time down to average annual figures for purposes of simplicity. Either way, the problem solver ends up with a cost per unit figure which he can compare to other alternative costs per unit produced.

An example of the cost effectiveness test is provided here for illustrative purposes. Suppose, you have

identified three alternative automated storage and retrieval systems that all have ten year expected lives and output rates of 8000 issues per day for Alternative 1, 7500 issues per day for Alternative 2, and 6000 issues per day for Alternative 3. Suppose their estimated total discounted life cycle costs are $6,336,000, $6,517,590, and $4,686,000, respectively. Assuming that there are 220 working days per year, the cost effectiveness ratios would be:

Alternative 1:

$$\frac{\$6,336,000}{220 \times 8000 \times 10} = \$.36/\text{Issue}$$

Alternative 2:

$$\frac{\$6,517,590}{220 \times 7500 \times 10} = \$.395/\text{Issue}$$

Alternative 3:

$$\frac{\$4,686,000}{220 \times 6000 \times 10} = \$.355/\text{Issue}$$

The criteria used for evaluating and ranking would be most performance per unit of cost or lowest cost per unit of activity.

(4) Break-even Analysis. The break-even analysis is a testing mechanism where alternatives are compared over either a time or level of activity line. The most frequent measure is the time line. Essentially this test consists of plotting annual variable cost (discounted) commencing at the fixed cost level over a time line for each alternative and then comparing the two. Figure 5 is an example of two systems tested under this mechanism. As can be seen, System 1 has a high fixed cost (capital investment or procurement) and a low variable cost (operating and maintenance)

while System 2 has a low fixed cost and a high variable cost. It is readily apparent from Figure 5 that Alternative 2 is the most economical (lowest total cost) up to 5 years, where both systems are equal on a cost basis. Beyond this point Alternative 1 is the most economical system. The determining factor is the expected useful life of the systems.

BREAK-EVEN ANALYSIS

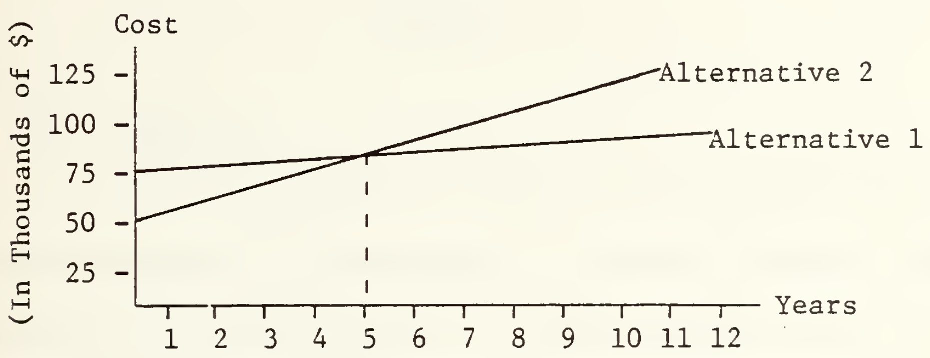


FIGURE 5.

As previously indicated, all alternatives should be tested including the no-change alternative. This provides a peculiar situation in that there is no fixed cost, therefore the variable cost line for the no-change alternative commences from the origin of the graph. The reason that capital expenditures for the current system are not considered here is that they are sunk costs and are not relevant. Therefore by comparing, say Alternative 1, incorporating an investment, with the current system and no change a graph such as Figure 6 would result. The same criteria applies to this situation as the prior one. What is the expected system life? If it is less than four years, then the no-change alternative is economically better.

BREAK-EVEN ANALYSIS

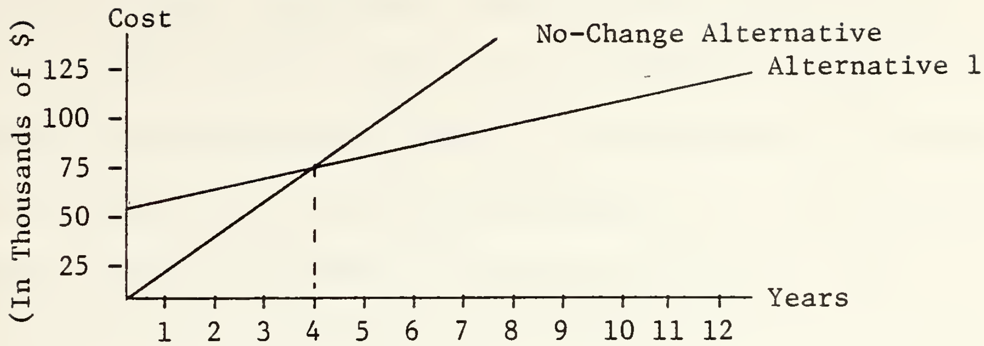


FIGURE 6.

2. Ranking

Establishment of order of preference is a difficult task because each situation is unique and the criteria of evaluation are different. To rank alternatives, the problem solver must design a scheme for weighting the criteria that will be utilized to evaluate test and analyses results. In other words, he must decide if all criteria are equally important, and if not, which are more important and how much more weight each should carry.

There is no easy guide to development of the weighting scheme in materials handling systems. Some of the data on weighting will arise from the analyses of the problem, some of the data may have been identified in the problem assignment and still other data on criteria weighting may be available through directives, regulations or command policies. Regardless of where the criteria originate and how much importance has been attached to each criterion, the problem solver must develop the total scheme for criteria weighting.

Economists have encountered a similar problem when attempting to rank individual preferences in an economic environment. Accordingly, they have developed utility theory for ranking preferences for various alternatives. Utility theory is nothing more than establishment of a ranking or comparison mechanism based on the ability of an item "to make an individual feel that he is better off"--a feeling of use or utility [23: 36]. The problem solver may find it benefitcial to apply utility theory in ranking of evaluation criteria if he has no other guidance or direction.

There are essentially two types of utility theory, Cardinal and Ordinal. Cardinal utility theory can be employed when the problem solver or decision maker can assign a level of utility to each criteria in terms of cardinal numbers (i.e. 1, 2, 10, 100, etc.). Ordinal utility theory is useful when the utility cannot be expressed in terms of cardinal numbers, but a weak order of preference can be stated. Cardinal utility is most useful if it can be employed, because it provides both magnitude and direction of preference or utility. Ordinal utility only indicates either a relative preference for or indifference between the alternatives considered. The problem solver will in most cases be forced into utilizing ordinal utility theory, because he will be unable to assign cardinal numbers to the utility attached to each criteria.

The problem solver may find the Delphi Technique a useful mechanism in assigning importance to the criteria

employed in the ranking scheme. He can do this by developing a questionnaire listing all evaluation criteria on which he can have his superiors or a selected panel of experts provide a relative order of preference among the criteria. Then he can collect the questionnaires and collate the data. Now by repeating the ranking process on the questionnaire and providing feedback to the rankers, the problem solver will be able to generate a consensus on the order of ranking of the criteria. This can give him some idea as to how to weight each criteria.

A suggested questionnaire form is provided in Appendix I which may be useful to the problem solver. It must be noted that the list of evaluation criteria is incomplete and the problem solver will have to include those dictated by the situation.

A few suggestions are offered in an attempt to help the problem solver with his task:

(1) Develop the criteria weighting scheme in an environment divorced from the alternatives to avoid built-in biases for particular alternatives (if possible, develop the scheme before the alternatives are known).

(2) Document the weighting scheme including the logic utilized in assessment of relative weights.

(3) Before selection of alternatives begins, attain command or management approval of the weighting scheme.

(4) Once a selection has been made, prepare a summary or overview of all alternatives to show how each stacked

up against the evaluation criteria (this will reveal the degree of relative closeness or equality between alternatives considered).

3. Other Considerations

Recent industrial and military experiences in implementing change in material distribution systems has revealed that at some point in the process of evaluation and selection of solutions, significant considerations are frequently overlooked. As a result, a series of typical costly problems arise. While it is possible that the analysis and generation of alternative solutions may have taken these considerations into account, the value of the time used in reviewing these considerations would be more than offset through reduction of the chance of a costly oversight.

The information about the considerations and problems presented below was supplied by top managers of major materials handling systems and military facility or activity managers. To avoid condoning or implicating either an individual, firm or activity, the sources having the specific problems will not be identified. The purpose of these comments is to provide potential users with valuable information learned through others' mistakes. The author in no way intends to be critical of the personnel involved and is not attempting to sit in judgement of them.

a. Personnel

"The most difficult task facing a project team in implementing an Automated Storage and Retrieval System

is dealing effectively with people at all levels in the company who are affected by the system [24: 62]." This fact has been repeatedly experienced by both industry and military facilities in their projects.

The most prevalent cause of personnel problems with automated systems is underestimation of the complexity of resulting tasks and over-confidence in the capabilities of the affected employees. As a result, the employees already anxious about their new jobs, are initially overwhelmed and frustrated in their new positions. A high percentage of system failures will result from personnel errors, some unintentional and some deliberate. Part of this problem can be overcome by education of the work force and by proper training. But it must be noted that basic intelligence levels and aptitudes may not be readily amenable to change.

With this fact in mind, management must take a hard look at the new task complexity and the current level of on-board talent. The question of personnel-system compatibility must be conscientiously settled before a commitment is made to a project. Seldom can an activity selectively release a significant portion of its labor force to recruit a work force with different aptitudes and a higher level of mental capability. Such an effort would result in serious labor relations problems and political reactions.

b. Procurement

While several types of contracts are utilized in system's procurement, the predominant problem encountered

with the contracting phase of the problem has historically been two-fold, (1) lack of a tight scope of work and (2) insistence on an equipment line or type. The first phase of this problem is related to the second in that the scope of work in the request for proposal or invitation for bid is usually incomplete and biased toward an equipment concept or type. Consequently, when the system's shortcomings are revealed, the buyer is forced to change the scope of work.

System manufacturers and suppliers indicate that on many contracts attractive alternate proposals are available, but they are never considered because the buyer restricts the proposals to a certain concept or a specific type of equipment supplied by a small number of firms. As a result, there is little or no competition between suppliers and a costly and frequently more risky proposal is accepted.

Associated with this situation is the fact that the automated materials handling industry is made up of two types of suppliers, manufacturers and brokers. Manufacturers design, make and install systems. Brokers buy subsystems from manufacturers and install them as integrated systems. There are a large number of reputable and capable firms in both areas. Unfortunately, there are also some not-so-reputable suppliers.

The system buyer accepts the highest risk of problems or project failure when dealing with a small broker. Small brokers generally have limited engineering

capability and little capability in the heavy rework area needed for integration of subsystems. Therefore, they are dependent upon subcontracting major portions of the work to other firms. The successful broker is a capable and qualified engineer, contract administrator, computer programmer, financial manager, systems analyst and a master organizer. This is a hard combination to come up with. The larger firms have a wider base from which to draw these talents and resources.

An associated procurement problem noted by one major system manufacturer deserves mention here. After many years of observing government procurement of automated and mechanical systems, a senior executive of one firm has noted that the predominant reason that most of the unsuccessful systems failed is that actual funding prohibited procurement of the envisioned system. Rather than accepting system parameter changes or going to a phased procurement, the project manager resorted to internal specification changes which affected the integrity of the total system. The results of such actions were easily predictable. In this situation, phased procurement may be the answer because automated materials handling systems can be procured in modules and with different levels of control with significant cost savings. In addition, later procurement under an expansion or up-grading program was possible with minimal economic penalty or lost sunk costs.

c. Maintenance

Although maintenance is not a problem until the system is installed and running, one of the early decisions that needs to be made before development of a contract to procure equipment is who will be doing the maintenance? The question and answer is three-fold in that one must consider (1) electrical-mechanical equipment maintenance, (2) computer maintenance, and (3) software maintenance.

Maintenance costs can be a significant factor during the alternative selection process. But equally important is the fact that the level of maintenance or lack thereof will directly determine continuing system performance and availability plus eventual system life. Regardless of whether maintenance will be accomplished in-house or by contract, the talent must be available when needed. A super-sophisticated system that performs spectacularly when it is working is worthless if you can't get it fixed when it is inoperative.

The system buyer should attempt to determine the availability and quality of service available before commitment to a system. If the decision is to go in-house, training of maintenance personnel ought to be an item in the contract. For software, several major manufacturers recommend that the buyer provide systems or program analysts to work with the supplier's programmers. The benefit here is that the analysts do not have to attempt to learn the system from the supplier's documentation after delivery and the

analysts are better qualified to speak to the completeness and quality of the system's program documentation.

d. Real-Time Systems

Most of the automated systems today are real-time systems. In such systems, the equipment operators are interacting with the computer control system and have direct access to the data base. As such, there is a need for positive control and a protection mechanism for the data base.

The computer manufacturers have developed an array of interlocking devices that can block access to certain portions of the data base and they have devised various security keys to limit access to the system, but they have not come up with a positive control. With current computer speeds, it is impossible to provide a fail-safe control monitor. Control in the system is still reliant upon the supervisor or analyst spot checking individual records or activities, manually reviewing periodic records, trouble shooting and special file reconstructions.

As far as protection of the data base is concerned, it is dependent on the operators. If they are capable and well trained, the data base is relatively safe from accidentally being wiped out. But full protection from unintentional mistakes or deliberate destruction is currently not technically possible on real-time systems. The risk of this happening increases proportionately with the number of people or operators interacting with the data base. In such a situation, the file recovery is

dependent upon the availability of daily transaction records for the period involved. File reconstruction involves considerable effort and computer time.

4. <u>Presentation of Alternatives and Recommendations</u>

It is possible that the problem solver may not be the individual responsible for making the final decision with regard to selection of the solution. Frequently the problem solver is commissioned by an organization's management to investigate a problem, develop a series of alternatives and recommend a solution. If he is not the final decision maker, he must present his findings and recommendations to the decision maker.

The presentation should consist of the following elements: (1) a brief statement of the problem, (2) a description of the assumptions (if applicable) and analytical procedures used, (3) a list of all alternatives considered, (4) a ranking of all alternatives with a brief explanation of the ranking process, and (5) a recommendation with supporting materials and/or facts. It is essential that the non-quantifiable costs and benefits be presented at this time for consideration by the decision maker.

At this point, responsibility for the decision or selection of a solution passes to the decision maker. He will make the decision incorporating the problem solver's presentation, the non-quantifiable benefits and costs, possibly other facts not known by the problem solver, and his own subjective judgement. While the decision is solely

the decision maker's, a well prepared and executed presentation on the part of the problem solver can be extremely influential in the decision making process.

F. IMPLEMENTATION

Often the problem solver finds that the implementation of a decision or alternative is more difficult than the decision making process itself. Inadequate planning and lack of control during implementation have led to the failure of more than one well developed and sound solution. Success in problem solving situations is equally dependent on both decision making processes and implementation.

A modern materials handling system is a very complex and costly solution to a problem. It could easily cost in excess of $12,000,000 and take several years to implement. Depending upon the method of procurement, the need for coordination between buyers and suppliers could become critical.

Implementation is basically a planning and management control process. Most successful projects, whether large or small are dependent upon three elements in the implementation phase, (1) personnel, (2) planning and management tools and (3) a performance testing or evaluation mechanism. The personnel provide the element of control, the planning tools provide a means for monitoring progress and the testing mechanism provides a basis for acceptance and actual evaluation of the final solution. All of these elements are equally important to the successful implementation of a project or a major system change.

1. Personnel

Consistent with modern management practices, the person held responsible for a task must have the authority to make the decisions and to commit the resources needed to accomplish the task [10: 393]. During implementation of a solution, the problem solver is the responsible project manager. As the project manager he must function as the central coordinator between interacting project elements (contractors, activity organizational subelements, etc.) and as the unified communications link between the buyer and seller. If both of these conditions are not met, then the project manager has lost control over the situation he is responsible for.

Major manufacturers of materials handling systems and equipments recommend in their system planning literature that customers set up a formal project management team headed by a designated project manager [25]. They further recommend that this team serve as the single communications link and as the central coordinator, primarily for the purpose of maintaining control. Their experiences indicate that lack of unity in purpose and direction by both buyer and supplier leads to higher costs, confusion, misunderstandings and a poor product. Here is where control pays off; it proves that unity.

2. Planning and Management Tools

The need to plan has become more apparent to the military services and industry with increasing complexity

of systems and rising costs. In response to this situation a variety of formal planning tools have been developed which have since been proven to be valuable project management methods. Some of the planning tools are simple and others are complicated and detailed. The more complicated ones cost more and generally need computer services to be maintained. The project manager must decide the level of investment needed for this service based on the situation and the total project cost.

Probably the simplest planning tool is the milestone chart or Gantt chart. It is a timeline chart with major events or milestones in the project indicated at the estimated points in time where task completion should occur if the project goes according to plan. It is the easiest tool to prepare and use, but it provides the least amount of information. It is also the cheapest.

The construction industry has found the Critical Path Method (CPM) to be an extremely valuable planning and management tool. It basically indicates the expected project completion date by tracking the longest series of precedent-related tasks or activities through the project network. A network is a graphical depiction of a project reflecting the precedence relationships of all tasks and activities. It is more detailed than a milestone chart, and it identifies critical relationships by task with respect to specific times. CPM can be used in a manual mode for small projects with a limited number of activities, but

it is too time consuming and difficult to maintain manually. Large complex projects should make use of commercially available computer software.

Another useful planning tool is the Program Evaluation Review Technique (PERT) which is similar to CPM, but it applies a probability distribution to the task-time relationships. While very detailed and more costly to prepare, this tool can be extremely helpful on long, envolved, high risk and high cost projects. Projects that are dependent upon research and development or that incorporate advanced state-of-the-art design that hasn't been proven, are good applications for this tool.

The advantage of using this tool is that it focuses management attention on the uncertainty of events and their associated impact on times and relationships with respect to project progress.

3. Performance Testing and Evaluation

The final phase of the decision making or problem solving process is performance testing and evaluation of the solution. Throughout the decision making process, various tests and simulations were conducted to predict the feasibility and acceptability of all alternatives. One of these alternatives was selected and implemented as a solution. If the solution involved procurement under a performance specification, acceptance testing is needed to verify delivery within the terms of the contract. Even if this is not the case, the problem solver-project manager is obligated

to conduct performance testing and evaluation to ensure that planned objectives and goals were attained.

Total system performance testing should occur at the close of the project. The system should be evaluated within the operating environment identified in the problem definition. After this evaluation, the system should be evaluated within the existing operating environment. Specific test plans and procedures should be developed for each situation to assure the validity of the evaluation. The reasons that the system ought to be evaluated both ways are that: (1) the definition of the environment may have been inaccurately stated, or (2) the operating environment could have changed and not been noticed during implementation. Either way, feedback is needed to provide information on how effective the solution was.

If there is a noted difference, minor changes may be needed or the whole decision making/problem solving process may have to be repeated to gain an acceptable solution. Large investments of funds and time do not necessarily guarantee successful solutions. The successful solution to a problem is the one that has proven through performance that it has accomplished its mission.

III. SUMMARY

The decision making model developed in this thesis was an adaptation of Ross A. Webber's basic decision model. It was selected because (1) it approached the decision making process as a problem solving session employing cause-effect relationships and (2) it was readily adaptable to the material distribution system environment.

The importance of proper definition of the problem was stressed and generation of multiple alternatives was highlighted to encourage an active search for better solutions. A series of suggested formats, techniques, examples and references were provided as an aid to the problem solver or decision maker. It must be noted that each situation is unique and that the decision model and the various guides are general and not all inclusive. They provide a good starting point for project definition when one is faced with a need for improved productivity or change in a material distribution system. They are flexible and can be adapted to fit almost any situation. Those areas that do not fit a specific application can be eliminated, and those areas that are not adequate can be changed or expanded at the problem solver's discretion.

The selection of a solution is always a difficult task primarily because it is not always obvious what characteristics should be evaluated and secondly, weighting of evaluation criteria employed in the ranking process is heavily

influenced by subjective factors. Some suggestions were provided to aid in this task. In addition, experiences that both industry and military managers have encountered when automation was employed to improve productivity are provided. These experiences can be equated to lessons learned and could possibly be of value to future systems planners in making selection.

While the magnitude of the problem of implementing a system change may appear overwhelming, it can be accomplished if approached one step at a time. The basic structure of the decision model promotes this approach.

APPENDIX A

CURRENT PRODUCTIVITY IMPROVEMENT PROJECTS

Activity[1]	Location	Project Name[2]	Status[3]
ALC San Antonio	Kelly AFB, Texas		C
ALC Oklahoma City	Tinker AFB, Oklahoma	WICS	C
ALC Warner Robins	Robins AFB, Georgia	WICS	C
ALC Ogden	Hill AFB, Utah	SARS	C
ALC Sacramento	McClellan AFB, California	STACS	UD
DGSC Richmond	Richmond, Virginia	DISARS	UC
NARF North Island	San Diego, California	ASKARS	UC
NARF Norfolk	Norfolk, Virginia	ASKARS	UC
NARF Jacksonville	Jacksonville, Florida	ASKARS	UC
MCAS Cherry Point	Cherry Point, North Carolina	ASKARS	UC
NAF Indiannapolis	Indiannapolis, Indiana	ASKARS	UC
NSC Oakland	Oakland, California	NISTARS	UD
NSC Norfolk	Norfolk, Virginia	NISTARS	UD
NSC San Diego	San Diego, California	NISTARS	UD
NARF Alemeda	Oakland, California	ASKARS	UD
NAS Pensacola	Pensacola, Florida	ASKARS	UD

Notes:

1. Activity Abbreviations:

   ALC - Air Logistics Center
   DGSC - Defense General Supply Center
   NARF - Naval Air Rework Facility
   MCAS - Marine Corps Air Station
   NAF - Naval Avionics Facility
   NSC - Naval Supply Center
   NAS - Naval Air Station

2. Project Abbreviations:

   WICS - Warehouse Information Control System
   SARS - Storage and Retrieval System
   STACS - Storage Transfer and Control System
   DISARS - Depot Integrated Storage and Retrieval System
   ASKARS - Automated Storage, Kitting and Retrieval System
   NISTARS - Naval Integrated Storage and Retrieval System

3. Status Abbreviations:

   C - Completed and in Operation
   UD - Contract Under Development
   UC - Under Construction

APPENDIX B

PREPARATION OF AN ORGANIZATION/OPERATIONAL PROCESS REVIEW

As previously stated, the purpose of the Organization/Operational Process Review is to identify the differences between the system as it was designed and how it actually exists and operates. There are several ways to attack this problem and two methods are suggested here: (1) Organizational Chart and (2) Functional. Although both methods accomplish the same objective, the primary difference is the approach to the problem. The organization chart method relates functions, tasks and activities to organizational structure, whereas the functional method relates organizational elements to the functional structure of the activity.

A. Organizational Chart Method:

The organizational chart method employs comparing the existing organization chart to the organization as it is found from a review. The first step is to take the existing organization chart and add or list under each subelement its assigned functions, tasks and activities. The next step is to review the organization and prepare a new organization chart depicting the organization as it was found by the review. All functions, tasks and activities that are being accomplished within each subelement of the organization should be listed thereunder. See Figure B-1 for an example.

Visual comparison of the two charts will reveal the differences or variations which have occurred since the system was designed. These variations should be listed for analysis at a later time.

B. Functional Method:

The functional method consists of developing a basic functional chart of the organization by laying out the activity's functions in a logical sequence (i.e. parallel to operational or production processes or by grouping similar functions) and then listing their associated tasks and activities below. Like the prior method, the two charts should be prepared, one as it was designed and one as it was found during the review.

The next step in this method is to superimpose the organization command structure over the functional chart. The first chart will have the command structure as indicated in the organization manual. The second chart will reflect the existing organizational subelement boundaries.

Visual comparison of the two charts will reveal the additions, deletions and duplications of functions, tasks and activities within the organizational structure. These changes will be analyzed as to system impact later. Refer to Figure B-2 for an example. The specific items one should look for are:

1. Look for disjointed organizational alignment:

    a. More than one division responsible for the same function.

    b. More than one branch or section responsible for the same task.

    c. Unassigned organizational responsibility for a function, task or activity.

    d. An organizational subelement being held responsible for a function, task or activity and being required to report to another superior subelement that is not in its direct chain of command.

2. Look for duplication of functions, tasks or activities:

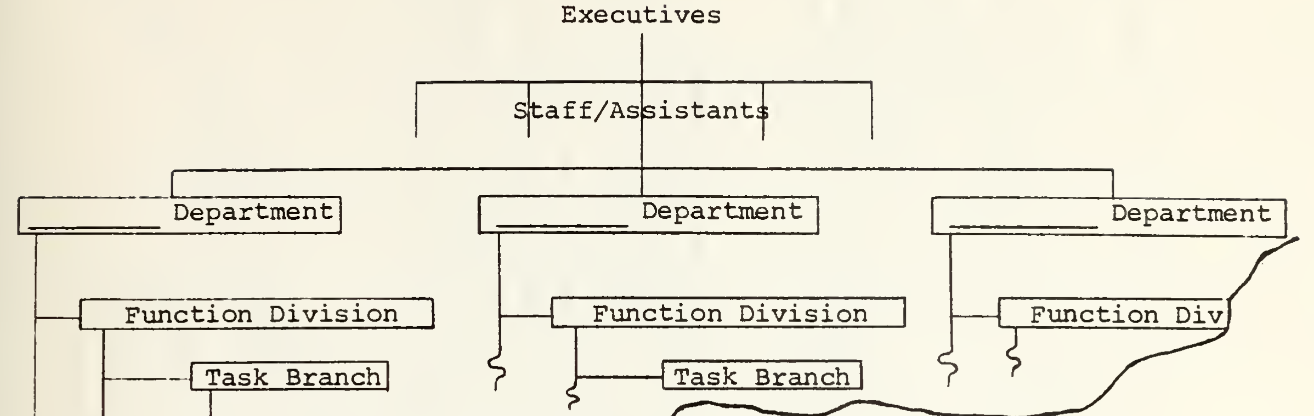
    a. Within Divisions

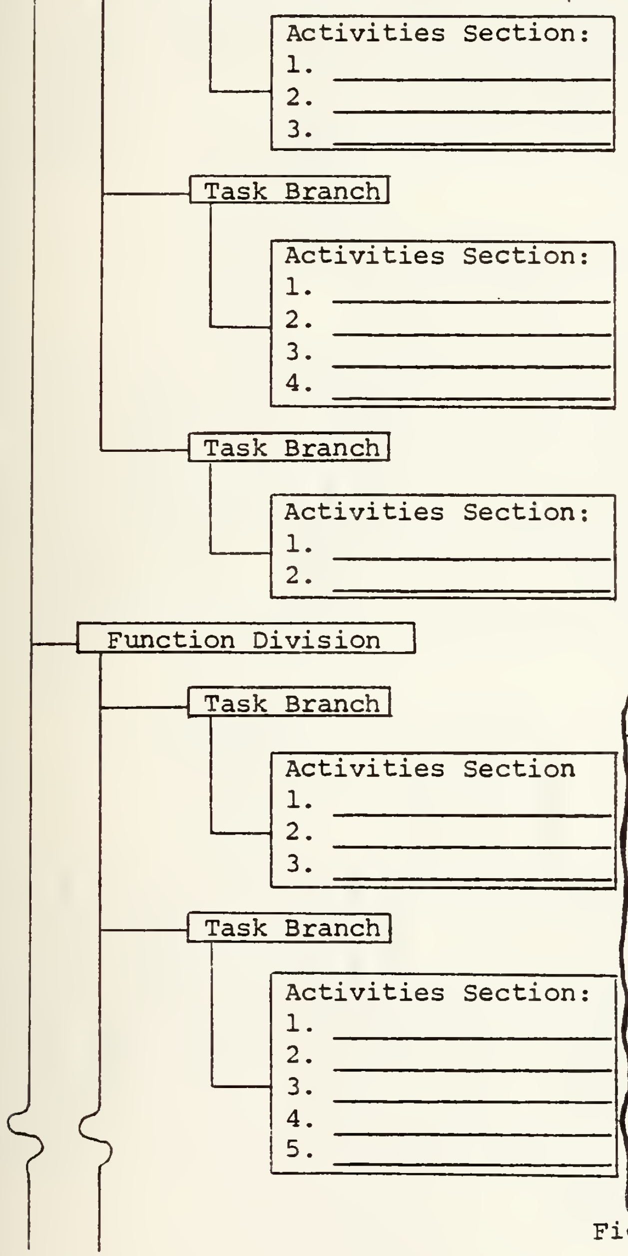
    b. Within Departments

3. Look for additions of new functions, tasks or activities.

4. Look for deletions of prior assigned functions, tasks, and activities.

ORGANIZATION CHART METHOD





Instructions:

A. As Designed:
(1) Identify the organizational structure from organization chart.
(2) List functions, tasks and activities under their assigned organizational subelements per the organization manual and applicable instructions.

B. As is Currently:
(1) Develpo organizational structure from findings of review.
(2) List functions, tasks and activities under the organizational subelements currently performing them.

C. Compare the two charts, noting the differences.

Example:

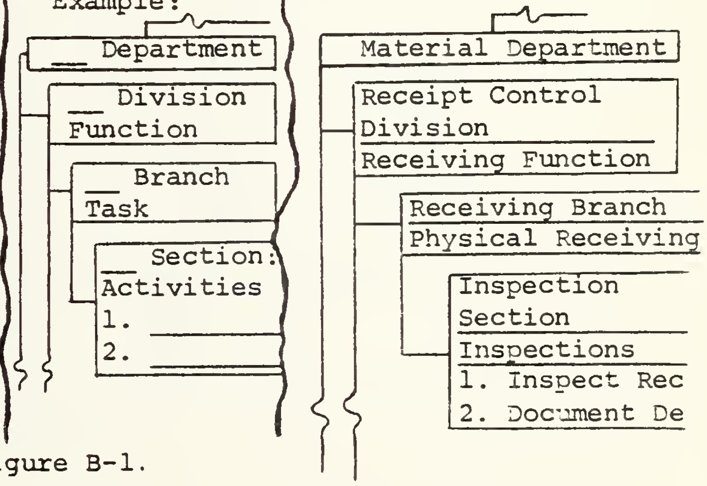
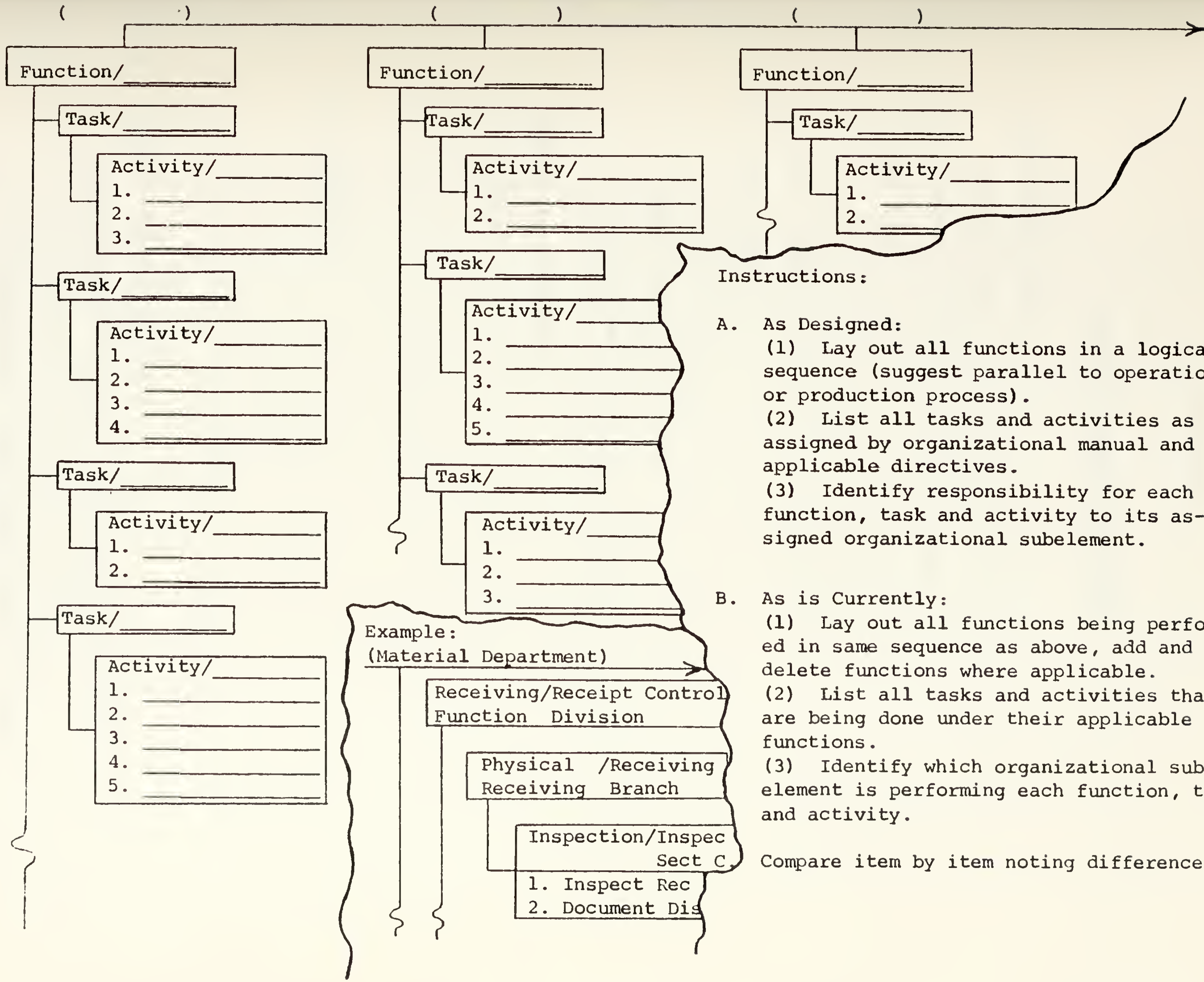


Figure B-1.

FUNCTIONAL METHOD



Instructions:

A. As Designed:
(1) Lay out all functions in a logical sequence (suggest parallel to operation or production process).
(2) List all tasks and activities as assigned by organizational manual and applicable directives.
(3) Identify responsibility for each function, task and activity to its assigned organizational subelement.

B. As is Currently:
(1) Lay out all functions being performed in same sequence as above, add and delete functions where applicable.
(2) List all tasks and activities that are being done under their applicable functions.
(3) Identify which organizational subelement is performing each function, task and activity.

Compare item by item noting differences.

Figure B-2.

APPENDIX C

GENERAL PLANNING DATA SHEET

I. IDENTIFICATION DATA:

A. Activity Name:____

B. Department, Division or Branch:__________________________

C. Address:____

____

D. Major Claimant:____

E. Project Office:

1. Project Officer:_____________________________________

2. Project Office Locations:____________________________

3. Telephone Number:___________________________________

II. ORGANIZATION OBJECTIVES:

A. Primary:

B. Secondary:

III. CURRENT SYSTEM PERFORMANCE

A. Primary Support Mission: (Check Applicable Blocks)

[ ] Material Distribution System Support:

[ ] System Support (Major Stock Point-Wholesale)

[ ] Regional Support (Specific Geographic Area of Support)

[ ] Intra-Activity Support

[ ] Intra-Departmental (Within a Specific Activity Subelement)

[ ] Transhipment Activities (Shipment Breakdown/Consolidation)

[ ] Production Support:

[ ] Temporary storage of Work-in-Process

[ ] Parts Support for Production Line

[ ] Part or Work-in-Process Kit Assembly

[ ] Storage Support:

[ ] Warehousing Operations:

[ ] Raw Materials

[ ] Work-in-Process

[ ] Finished Goods

[ ] Long Term Storage:

[ ] Committed Materials (Material Stored for a Designated Project-Prepositioned War Reserve Material Stocks, etc.)

[ ] Non-committed Stock (Inactive Material held as Safety Stock or Insurance Items)

B. General Description of Support Operations (As Identified in III-A):

C. Current Operational Performance Statistics (By Day if available, if not, by Month)

	MANUAL			COMPUTER		
1. Inventory Control Statistics (by line item)	High	Low	Ave.	High	Low	Ave.
a. Number of Stock Reviews	___	___	___	___	___	___

	MANUAL			COMPUTER		
	High	Low	Ave.	High	Low	Ave.
i. Items Added	___	___	___	___	___	___
ii. Items Deleted	___	___	___	___	___	___
iii. Orders Issued	___	___	___	___	___	___
b. Number Issue Requests						
c. Number Issue Requests Processed:						
i. Requests Filled	___	___	___	___	___	___
ii. Requests Referred	___	___	___	___	___	___
iii. Requests Backorder	___	___	___	___	___	___
iv. Requests Cancelled	___	___	___	___	___	___
v. Unprocessed Request (Backlog)	___	___	___	___	___	___
d. Number Status Messages Generated	___	___	___	___	___	___
e. Number of Personnel:						
i. Supervisors			___			
ii. Non-supervisors			___			
2. Financial and Property Accounting Statistics:						
a. Number Accounts Served	___	___	___	___	___	___
b. Number of Records Maintained	___	___	___	___	___	___
c. Number of Transactions Processed	___	___	___	___	___	___
d. Number of Reports Issued	___	___	___	___	___	___
e. Number of Transactions Unprocessed (Backlog)	___	___	___	___	___	___

	MANUAL			COMPUTER		
	High	Low	Ave.	High	Low	Ave.
f. Number of Personnel:						
i. Supervisory			___			
ii. Non-Supervisory			___			
3. Storage Statistics:						
a. Number of Receipts Processed	___	___	___			
b. Number of Receiving Material Inspections	___	___	___			
c. Number of Discrepancy Reports Submitted	___	___	___			
d. Number of Receipts Depacked	___	___	___			
e. Number of Receipts Repacked	___	___	___			

	MANUAL			AUTOMATED		
	High	Low	Ave.	High	Low	Ave.
f. Number of Receipts Stowed	___	___	___	___	___	___
i. In Bins	___	___	___	___	___	___
ii. In Pallet Racks	___	___	___	___	___	___
iii. In Bulk	___	___	___	___	___	___
iv. Other (Specify):						
(a)____________	___	___	___	___	___	___
(b)____________	___	___	___	___	___	___
v. Total Volume in Measurement Tons	___	___	___	___	___	___
g. Receiving Backlog (Receipts)	___	___	___	___	___	___
h. Number of Inventory Actions	___	___	___			

	MANUAL High	MANUAL Low	MANUAL Ave.	AUTOMATED High	AUTOMATED Low	AUTOMATED Ave.
i. Number of Material-in-Store Inspections	___	___	___			
j. Number of Repack/ Preservation Actions	___	___	___			
k. Number of Rewarehousing Actions	___	___	___			
l. Number of Orders Picked:						
i. From Bins	___	___	___	___	___	___
ii. From Pallet Racks	___	___	___	___	___	___
iii. From Bulk	___	___	___	___	___	___
iv. From Other (Specify):						
(a)____________	___	___	___	___	___	___
(b)____________	___	___	___	___	___	___
v. Total Volume in Measurement Tons	___	___	___	___	___	___
m. Order Picking Backlog (Issues)	___	___	___	___	___	___

n. Number of Personnel in:	Receiving	Storage
i. Supervisory	___	___
ii. Non-Supervisory	___	___

4. Material Handling Statistics:

	MANUAL High	MANUAL Low	MANUAL Ave.	AUTOMATED High	AUTOMATED Low	AUTOMATED Ave.
a. Number of Deliveries:						
i. To Intra-Activity	___	___	___	___	___	___
ii. To Local Delivery Customers	___	___	___			
iii. To Packing for Shipment	___	___	___	___	___	___
b. Number Special Hauls	___	___	___			
c. Delivery Backlog (days)	___	___	___			

	MANUAL			AUTOMATED		
	High	Low	Ave.	High	Low	Ave.
d. Number of Personnel:						
i. Supervisory			___			
ii. Non-Supervisory			___			

	MANUAL			MECHANICALLY		
	High	Low	Ave.	High	Low	Ave.
5. Packing Statistics:						
a. Number of Shipments Packed:						
i. For Local Delivery	___	___	___	___	___	___
ii. Consolidated Shipments	___	___	___	___	___	___
iii. Overpack Shipments	___	___	___	___	___	___
iv. Special Packs	___	___	___	___	___	___
b. Packing Backlog (orders)	___	___	___	___	___	___
c. Number of Personnel:						
i. Supervisory			___			
ii. Non-Supervisory			___			

6. Traffic Management Statistics:

a. Number of Shipments:

i. By Mode:	High	Low	Ave.
(1) Truck	___	___	___
(2) Train	___	___	___
(3) Ship	___	___	___
(4) Air	___	___	___
(5) Small Parcel Carrier	___	___	___

	High	Low	Ave.
ii. By Size			
(1) Piece	___	___	___
(2) Less than Carload	___	___	___
(3) Carload	___	___	___
(4) Bulk	___	___	___
b. Number of Routing Requests Issued	___	___	___
c. Number of Clearance/ Challenge Actions Sent	___	___	___
d. Number of Local Carrier Selections Made	___	___	___
e. Number of Documents Prepared	___	___	___
f. Number of Shipment Tracer Action Responses	___	___	___
g. Number of Transportation Descrepancy Reports Filed	___	___	___
h. Shipping Backlog:			
i. Awaiting Routing Request Submissions	___	___	___
ii. Awaiting Carrier Selections	___	___	___
iii. Awaiting Document Preparation	___	___	___

7. Inventory Statistics:

a. Stock Profile by Line Item: (Insert number of line items in blanks)

PROFILE CHARACTERISTICS	RANGES					
	0-1	1-4	4-16	16		
i. Size (in cubic feet)	___	___	___	___		
	.01-1	1-10	10-60	60-500	500-3000	3000
ii. Weight (in pounds)	___	___	___	___	___	___
	0-1	2-6	7-15	16-50	50	
iii. Demand (issues/year)	___	___	___	___	___	
	HiVal	Classi-fied	Con-trolled	Hazard	Other	
iv. Special Handling	___	___	___	___	___	
	Rectan-gular	Flat	Cylinder	Spher-ical	Irreg-ular	
v. Shape	___	___	___	___	___	

i. Special Inventory Environmental Requirements:

	Number Line Items	Total Cube
a. Special Temperature/ Humidity Control	_____	_____
b. Refrigerated		
i. Chill (33-38°F.)	_____	_____
ii. Frozen ($\leq 0°$ F.)	_____	_____
c. Explosion Proof	_____	_____
d. Toxic	_____	_____
e. Radiation Shielding	_____	_____

IV. CURRENT FACILITIES AND EQUIPMENTS

A. General Descriptions of Buildings (Include all physical dimensions of structure, number and dimensions of doors, number and sizes of loading docks, floor loading limitations, environmental controls and special features or constraints):

B. General Description of Materials Handling Processes (Slanted toward equipment activity):

C. Storage Aids (Dimensions in Inches: height-width-depth) (Check Applicable Block(s))

1. Type of Rack/Shelving Structure:

[ ] Bin (variable)

[ ] Mini-load (12 x 48 x 40)

[ ] Pallet (48 x 48 x 40)

[ ] Canlievered (variable)

2. Storage Aid Profile: (State all sizes in inches)

a. Bins:

	Number of Bins (A)	Bin Size (B) x (C) x (D)*	Bin Volume (B) x (C) x (D)	Compartments/ Bins (E)	Size of Compartments (F) x (G) x (H)*	Total Locations for Compartment Size (A) x (E)
(1)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(2)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(3)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(4)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(5)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(6)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(7)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
(8)	______	___ x ___ x ___	___ x ___ x ___	______	___ x ___ x ___	______
		TOTAL BIN VOLUME:	______		TOTAL BIN LOCATIONS:	______

*Note: B: height; C: width; D: depth; F: height; G: width; H: depth in feet

b. Mini-Load Racks:

	Number of Mini-Loads (A)	Mini-Load Size (B) x (C) x (D)*	Mini-Load Volume (B) x (C) x (D)	Compartments/ Mini-Load (E)	Size of Compartments (F) x (G) x (H)	Total Locations for Compartment Size (A) x (E)
(1)	______	x x	x x	______	x x	______
(2)	______	x x	x x	______	x x	______
(3)	______	x x	x x	______	x x	______
(4)	______	x x	x x	______	x x	______
	TOTAL MINI-LOAD VOLUME:		______	TOTAL MINI-LOAD LOCATIONS:		______

c. Pallet Racks:

(1) Single Bay (Rack Count x 1-pallet/rack) ______

(2) Double Bay (Rack Count x 2-pallets/rack) ______

TOTAL PALLET VOLUME ______ TOTAL PALLET RACK LOCATIONS: ______

*Note: B: height; C: width; D: depth; F: height; G: width; H: depth in feet

d. Other (Specify):

	Volume	Number Locations
(1) ______		
______	______	______
(2) ______		
______	______	______
(3) ______		
______	______	______
TOTALS:	______	______

e. TOTAL STORAGE CAPACITY BY VOLUME:
(Add Total Volumes from a thru d) ______

f. TOTAL STORAGE CAPACITY BY LOCATION:
(Add Total Number of Locations from a thru d) ______

D. EQUIPMENT STATISTICS (Check the Blocks and Fill in the Blanks)

1. Conveyers (in linear feet)

	Quantity	Rated Capacity
[ ] Gravity (Roller or Ball)	______	______
[ ] Powered		
[ ] Belt	______	______
[ ] Chain Driven Roller	______	______
[ ] Cross Bar	______	______
[ ] Trolly	______	______
[ ] Other (Specify):		
(a) ______	______	______
(b) ______	______	______

2. Sorting Devices:

[ ] Mechanical	______	______
[ ] Optical	______	______
[ ] Intelligent	______	______
[ ] Other (Specify): ______	______	______

		Quantity	Rated Capacity
3.	Monorail (Include number of carriers and description)		
	a. ______________________________		
	______________________________	______	______
	b. ______________________________		
	______________________________	______	______
4.	Pnuematic Tube (Include number of stations and description)		
	a. ______________________________		
	______________________________	______	______
	b. ______________________________		
	______________________________	______	______
5.	Cranes and Elevators:		
	[ ] Bridge Crane	______	______
	[ ] Stacker Crane	______	______
	[ ] Mobile Cranes	______	______
	[ ] Elevators:		
	[ ] Floor to Floor	______	______
	[ ] Continuous	______	______
	[ ] Other (Specify):		
	a. ______________________________	______	______
	b. ______________________________	______	______
6.	Industrial Vehicles:		
	[ ] Non-Powered:		
	[ ] Dollies	______	______
	[ ] Pallet Jacks	______	______
	[ ] Four Wheeled Trailers	______	______

	Quantity	Rated Capacity
[ ] Stackers	______	______
[ ] Other (Specify):		
a.____________________	______	______
b.____________________	______	______
[ ] Powered Vehicles		
[ ] Fork Trucks (List by Model and Size):		
a.____________________	______	______
b.____________________	______	______
c.____________________	______	______
d.____________________	______	______
e.____________________	______	______
[ ] Stacker Cranes (List by Model and Size):		
a.____________________	______	______
b.____________________	______	______
[ ] Straddle Trucks or Cranes (List by Model and Size):		
a.____________________	______	______
b.____________________	______	______
[ ] Tractor-Trailer Trains (List by Model, Size and Number of Trailers)		
a.____________________	______	______
b.____________________	______	______
[ ] Platform Lift (List by Model and Size):		
a.____________________	______	______
b.____________________	______	______

		Quantity	Rated Capacity
[ ]	Pallet Jacks (List by Model and Size):		
	a.________________________	______	______
	b.________________________	______	______
[ ]	Tow Line Systems (Describe and Indicate Number of Vehicles and their Capacity):		
	a.________________________		
	________________________	______	______
	b.________________________		
	________________________	______	______
[ ]	Wire-Guided Vehicles (Describe and Indicate Number of Vehicles and their Capacity)		
	a. ________________________		
	________________________	______	______
	b. ________________________		
	________________________	______	______
[ ]	Other (Describe):		
	a. ________________________	______	______
	b. ________________________	______	______
	c. ________________________	______	______

7. Automated Storage and Retrieval Systems (Describe Including Storage Capacity and Throughput)

a.

b.

	Quantity	Rated Capacity
8. Specialized Packing Equipment:		
[ ] Automatic Packers/Palletizers (Describe)		
a. ______________________	______	______
b. ______________________	______	______
[ ] Automatic Pallet Banders	______	______
[ ] Shrink Wrap Machines	______	______
[ ] Foam-In-Place Machines	______	______
[ ] In-Line Sizer-Scales	______	______
[ ] Other (Describe):		
a. ______________________	______	______
b. ______________________	______	______

V. FACILITIES AND EQUIPMENT MAINTENANCE AND OPERATING COSTS

	Averages Per Month			
	Maintenance			Operations
	Number Maintenance Actions	Total Man Hours	Total Cost	Total Costs*
A. Building Maintenance by Building:				
1. ______________________	_____	_____	_____	_____
2. ______________________	_____	_____	_____	_____
3. ______________________	_____	_____	_____	_____
4. ______________________	_____	_____	_____	_____
5. ______________________	_____	_____	_____	_____
6. ______________________	_____	_____	_____	_____
TOTALS BUILDING MAINTENANCE	_____	_____	_____	_____

*Includes telephone, garbage, utilities, lubricants and fuels.

	Averages Per Month			
	Maintenance			Operations
	Number Main-tenance Actions	Total Man Hours	Total Cost	Total Costs*
B. Storage Aid Maintenance:				
1. Bins	____	____	____	____
2. Mini-Load Racks	____	____	____	____
3. Pallet Racks	____	____	____	____
4. Canliever Racks	____	____	____	____
5. Other	____	____	____	____
TOTALS STORAGE AND MAINTENANCE	====	====	====	====
C. Equipment Maintenance:				
1. Conveyers	____	____	____	____
2. Monorail	____	____	____	____
3. Pnuematic Tube	____	____	____	____
4. Cranes and Elevators:				
a. Bridge Cranes	____	____	____	____
b. Stacker Cranes	____	____	____	____
c. Mobile Cranes	____	____	____	____
d. Elevators	____	____	____	____
e. Other	____	____	____	____
TOTAL (CRANES AND ELEVATORS)	====	====	====	====
5. Industrial Vehicles:				
a. Non-powered	____	____	____	____
b. Powered:				
i. Fork Trucks	____	____	____	____
ii. Stacker Cranes	____	____	____	____

*Includes telephone, garbage, utilities, lubricants and fuels.

	Averages Per Month			
	Maintenance			Operations
	Number Main-tenance Actions	Total Man Hours	Total Cost	Total Costs*
iii. Straddle Trucks and Cranes	____	____	____	____
iv. Tractor-Trailer Trains	____	____	____	____
v. Platform Lift	____	____	____	____
vi. Pallet Jacks	____	____	____	____
vii. Tow Line Systems	____	____	____	____
viii. Wire-Guided Vehicles	____	____	____	____
ix. Other	____	____	____	____
SUBTOTAL POWERED	____	____	____	____
TOTAL INDUSTRIAL VEHICLES	====	====	====	====
6. Automated Storage and Retrieval Systems:				
a. ____________	____	____	____	____
b. ____________	____	____	____	____
TOTAL ASRS	====	====	====	====
7. Specialized Packing Equipment:				
a. Automatic Packers/ Palletizers	____	____	____	____
b. Automatic Pallet Banders	____	____	____	____
c. Shrink Wrap Machines	____	____	____	____
d. Foam-IM-Place Machines	____	____	____	____
e. In-Line Sizer-Scales	____	____	____	____

*Includes telephone, garbage, utilities, lubricants and fuels.

	Averages Per Month			
	Maintenance			Operations
	Number Maintenance Actions	Total Man Hours	Total Cost	Total Costs*
f. Other	____	____	____	____
TOTAL SPECIALIZED PACKING EQUIPMENT	====	====	====	====
8. Total Equipment Maintenance (Add Totals 1 through 7)	====	====	====	====
D. Total For All Facilities and Equipment (Add Totals for A, B, and C)	====	====	====	====

VI. OPERATION AND LABOR COST STATISTICS

	Number Supervisors	Number Non-Supervisors	Number Man Hours	Labor Cost	Supply Costs*
A. Inventory Control:					
1. Customer Service	____	____	____	____	____
2. Stock Control	____	____	____	____	____
3. Purchase	____	____	____	____	____
Total Inventory Control	====	====	====	====	====
B. Property and Financial Accounting:					
1. Planning and Budget	____	____	____	____	____
2. Accounting	____	____	____	____	____
3. Payroll	____	____	____	____	____
4. Property Account Records	____	____	____	____	____
5. Internal Review	____	____	____	____	____
TOTAL PROPERTY AND FINANCIAL ACCOUNTING	====	====	====	====	====

	Number Super-visors	Number Non-Super-visors	Number Man Hours	Labor Cost	Supply Costs*
C. Storage:					
1. Receiving	____	____	____	____	____
2. Warehousing	____	____	____	____	____
Total Storage	====	====	====	====	====
D. Material Handling:**					
1. Material Handling Equipment	____	____	____	____	____
2. Transportation/ Delivery	____	____	____	____	____
3. Labor Services	____	____	____	____	____
Total Material Handling	====	====	====	====	====
E. Packing:					
1. Small Parcel Packing	____	____	____	____	____
2. Large Parcel Packing	____	____	____	____	____
3. Special Packing	____	____	____	____	____
4. Preservation	____	____	____	____	____
Total Packing	====	====	====	====	====
F. Traffic Management:					
1. Shipment Planning	____	____	____	____	____
2. Carrier Selection	____	____	____	____	____
3. Transportation Services	____	____	____	____	____
Total Traffic Management	====	====	====	====	====

	Number Supervisors	Number Non-Supervisors	Number Man Hours	Labor Cost	Supply Costs*
G. TOTAL OPERATIONS AND LABOR COSTS (Add Totals A through F)	____	____	____	____	____

Notes: * Cost of supplies includes all costs of materials and services consumed by applicable cost centers. Maintenance and utilities costs for the facilities are excluded.

**Costs for fuels and lubricants, repair and maintenance materials and maintenance labor are excluded.

APPENDIX D

INSTRUCTIONS ON PREPARATION OF DAILY ACTIVITY PROFILE

The purpose of the Daily activity Profile is to identify the hourly activity rates and peak loading periods. Problem solvers and managers can utilize the work load distribution data for planning both personnel allocations and in evaluating needed equipment capacities.

The sample Daily Activity Profile provided herein covers only one critical task where a system bottleneck typically occurs. Depending on the situation and the specific installation, other tasks may be the critical ones and are the system's bottlenecks. The problem solver should look for these areas, collect the applicable data and plot the activity profiles.

The Daily Activity Profile is a general use format that can be universally employed in the analysis of functional and task areas. The data needed for the analysis may be available from existing work measurement reports of management information system reports. If not, the problem solver will need to set up an appropriate sampling plan to collect the data.

Instructions for Preparation of Daily Activity Profiles follows:

I. Schedule:

1. Fill in heading blocks:

   A. Insert title of functional or task area.

   B. List all applicable activities.

   C. Insert the date of preparation.

   D. Insert period from which data averages were taken.

   E. Enter name of individual preparing the profile.

2. Insert average hourly figure for each activity under the appropriate hour of the day column.

3. Sum figures for each activity horizontally and insert the total in the total column next to the activity.

4. Sum figures by vertical columns and insert the totals in the total by hour blocks at the bottom of the schedule.

II. Profile:

1. Establish vertical axis index for profile based on range of totals by hour.

2. Identify units measured on vertical axis index (i.e. Packs, Issues, Demands, Receipts, Receipts Processed, etc.)

3. Plot hourly data in appropriate column and connect plot points (data used is totals by hour).

Optional Step:

If a maximum capacity or a limiting constraint is known, that constraint can be overlayed on the profile. When the activity level reaches the constraint level, like the period between 1300 and 1500 in Figure D-1, a critical period has been identified. A critical period is the timeframe when activity level equals or exceeds planned output capacity. Although most management would prefer to man the

function at a level where output capacity equals activity level, this is not prudent nor is it feasible to do so when activity is generated randomly from outside of the system.

Credit: Adapted from an example in Eaton-Kenway Incorporated's planning manual, How to Plan an Automated Small Parts Order-Picking System, p. 22, 1974.

DAILY ACTIVITY PROFILE
(Hourly Averages)

A. ____________________
(Function/Task)

Date: ____________________
Data Period: ____________________
Prepared by: ____________________

B. Activities:

I. SCHEDULE

Hours of the Day

	AM					PM												AM						
Total	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7
Totals by Hour																								

II. PROFILE

(Units Measured)																								
	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7

DAILY ACTIVITY PROFILE
(Hourly Averages)

A. Packing Activity
(Function/Task)

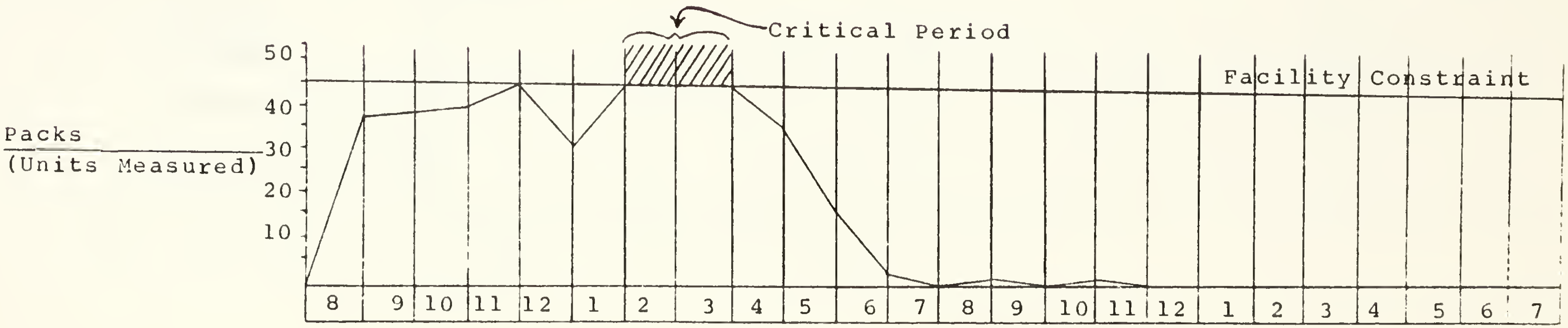
Date: 11 Oct 78
Data Period: 1 Sep to 30 Sep 78
Prepared by: G. R. Boyt

I. SCHEDULE

B. Activities: Hours of the Day

		AM					PM											AM						
	Totals	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7
1. Unscheduled Packs																									
a. Transportation Priority I	6					1		1		1	1	1				1									
b. Special Projects (NORS, 999)	12	1				2	1	1	3	1	2			1											
2. Scheduled Packs																									
a. Transportation Priority 2	149	15	10	12	15	10	20	18	20	12	15	2													
b. Transportation Priority 3	213	21	28	27	30	15	24	25	22	21															
Total by Hour	380	37	38	39	45	28	45	45	45	35	18	3		1		1									

II. PROFILE



APPENDIX E

EXAMPLE OF GENERAL PLANNING DATA SHEET
(SUMMARY WORKSHEET)

	Current System Capability			Forecasted Changes			Near-Future System's Requirement			Updated Goals & Objectives			Differences		
	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.
3. Storage Statistics															
				Subtract (500-550)							To Get			Deficiency	
a. Number of Receipts Processed	500	250	325	550	0	350	550	250	350	550	250	350	-50	0	-25
b. Number of Receiving Material Inspections	20	5	14	25	0	16	25	5	16	20	5	14	0	0	0
c. Number of Receiving Discrepancy Reports Submitted	210	125	175	225	0	190	225	125	190	225	150	200	-15	-25	-25
													Excess Capacity		
d. Number of Receipts Depacked	45	15	22	40	10	19	40	10	19	40	15	19	+5	0	+3
							Subtract (22-19)						To Get		
6. Traffic Management															
a. Number of Shipments															
(1) By Mode:															
(a) Truck	25	10	18	30	0	24	30	10	24	30	10	24	-5	0	-6
(b) Train (Box Cars)	5	1	3	3	0	0	3	1	3	3	1	3	+2	0	0
(c) Ship (Containers)	2	0	1	8	2	4	8	2	4	4	2	3	-2	-2	-2

Note: Data selectively developed to illustrate the process

APPENDIX F

EXTRACT FROM NAVSUP PUBLICATION 529
"WAREHOUSE MODERNIZATION AND LAYOUT PLANNING GUIDE"

Extract fom the Table of Contents:

Extract from the Introduction

1.2 ORGANIZATION OF PUBLICATION

The development of this type of guide is something like a "chicken and egg" situation. If one does not go into some detail about equipment before discussing layout and system design techniques, the uninitiated user may find himself bewildered by the criteria and procedures. Conversely, presentation of layout modules prior to a discussion of system selection techniques may appear to be arbitrary. For this and other reasons, the Publication is organized into a series of four parts (I, II, III, and IV) that provide:

I. A general discussion of design criteria, state-of-the-art equipment and concepts, operating configurations and their applicability in various facility situations. This part also contains a review of available representative vehicular equipment, storage equipment, and mechanization capabilities to familiarize the user with the hardware market as it existed at the time this Publication was prepared.

II. A general presentation of procedures for system selection and integration of storage areas and support areas in either existing or new facilities, sample applications of such procedures, and design concepts for typical Navy General Supply Facilities. Introductory comments in this Part alert the reader to prerequisite requirements of the Navy's Shore Installations and Facilities Planning and Programming System and provide an outline of the Navy's requirements planning procedures for General Supply Facilities. Introductory guidance includes identification of interfacing parameters and common terms applicable to design procedures of the Publication and to prerequisite Navy General Supply Facilities requirements planning systems.

III. A presentation of planning data, including tables, charts, graphs, illustrations, and modular layouts with elevation views, to support the procedures and sample applications presented in Part II. Sections 16 and 17 provide modular layouts and data for pallet handling and order picking systems. Such layouts and data are based on time standards, equipment standards, and specific operational sequences which are explained in detail in the support data in Part IV, Section 19. The use of standards in a comparative cost analysis provides for optimum system selection and preliminary design of Storage Areas based upon transaction and inventory data. Section 18 provides Support Area (S) design criteria and data pertaining primarily to shipping and receiving dock areas. Introductory comments and summary Layout Planning Charts are furnished at the beginning of Part III to provide a capsulated overview of the numerous pallet handling and order picking modules. These charts are also reproduced as foldout wall charts.

IV. Section 19 contains the detailed time, cost, equipment, operation sequence, and comparative cost analysis standards as a backup for the planning data in Part III. Section 20 provides an outline of procedures to be followed when deviation from these standards is necessary in order to proceed beyond the comparative analysis stage. This Section outlines the procedures necessary to properly modify the various standards and also provides additional information on factors which need to be investigated before a system design is finalized. These factors include items such as floor load requirements, sprinkler systems, construction tolerances, and rack deflections.

Additionally, five appendicies are included with the initial printing of this Publication:

Appendix A. This Appendix furnishes a listing of reference books and magazines for supportive technical information that will be necessary or helpful in using this Publication and in keeping abreast of changes in state-of-the-art techniques and equipment. This information, when coupled with vendor literature on equipment cost and operational characteristics, will be invaluable in preliminary designs and layouts developed through use of the contents of this Publication into final or near-final designs.

Appendix B. This Appendix furnishes formulas, definitions of terms, and other pertinent information extracted from other Navy Publications that will be useful in correlating the planning procedures contained in this Publication with other Navy Directives.

Appendix C. This Appendix furnishes alternative tables for pallet handling layout modules having vertical pallet level openings of approximately 63 inches. The applicable data and elevation views for the pallet handling systems presented in Section 17 provide for average vertical pallet level openings of approximately 45 inches. The 45-inch openings represent standard Navy DOD practice and provide for storage of about one measurement ton (M/T) per pallet. The 63-inch openings accommodate about 1.5 M/T per pallet and represent the maximum vertical opening that will be applicable, for example, when only clothing and/or dry subsistence items are to be stored.

Appendix D. This Appendix furnishes guidance in determining allowable loadings of ground floor levels in existing facilities.

Appendix E. This Appendix furnishes information for estimating the cost of sprinkler systems in the various storage configurations.

APPENDIX G

THE PROCESS

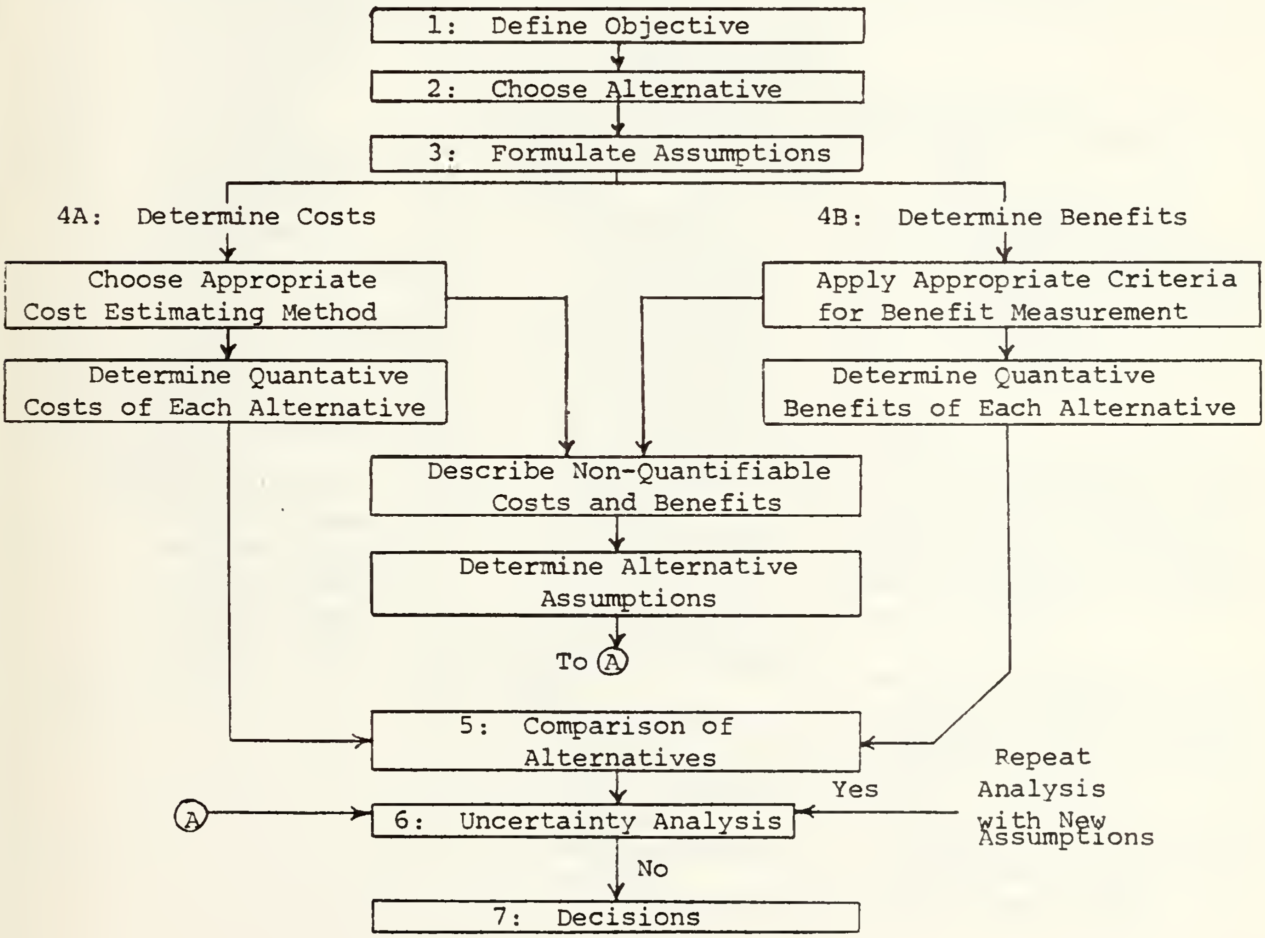
Economic analysis is a conceptual framework for systematically investigatine problems of choice. An economic analysis postulates alternative means of satisfying an objective and investigates the costs and benefits of each of these alternatives. This orderly, comprehensive presentation of the important considerations of each alternative assists the manager in making and reviewing decisions. It does it by:

(a) Focusing informal thinking.

(b) Surfacing hidden assumptions, making clear the considerations which support a recommendation.

(c) Providing an effective vehicle for communicating the considerations which support a recommendation.

The key elements of an economic analysis are: (1) establishing and defining the goal or objective desired, (2) searching out hypothetical alternatives for accomplishing the objective, (3) formulatinf appropriate assumptions, (4) determining the cost (inputs) and benefits (outputs) of each alternative, (5) comparing costs and benefits of all alternatives and ranking the alternatives, and (6) testing the sensitivity of major uncertainties on the outcome of the analysis.



SOURCE: Extracted from Chapter I of the Department of Defense Economic Analysis Handbook, Second Edition, Undated.

APPENDIX H

TOTAL COST

ACQUISITION COSTS

1. Contract Development and Administration
   - A. Personnel
   - B. Contract Administration
   - C. Inspection and Technical Services
   - D. Acceptance Testing
2. Systems Costs
   - A. Facilities
     - (1) New Construction
     - (2) Modifications
   - B. Hardware
     - (1) Equipment
     - (2) Computer
   - C. Software
   - D. Personnel Training
   - E. System Documentation
3. Initial Logistics Support
   - A. Spare Parts
   - B. Contract Maintenance Support
   - C. Software Maintenance Support
   - D. Contract Services

OPERATIONS COSTS

1. Personnel
   - A. Direct Labor
   - B. Indirect Labor
   - C. Training
   - D. Overhead
2. Direct Operating Costs
   - A. Direct Materials
   - B. Utilities
   - C. Fuel (Non-ing)
   - D. Purchased Services
   - E. Transportation
3. Facilities and Equipment Maintenance
   - A. Preventive
     - (1) Facilities
     - (2) Equipment
     - (3) Computers
   - B. Minor Repair
     - (1) Facilities
     - (2) Equipment
     - (3) Computers
   - C. Major Repair or Overhaul
     - (1) Facilities
     - (2) Equipment
     - (3) Computers
4. Software Maintenance
   - A. Routine Program Maintenance
   - B. Minor Program Changes
   - C. Program Modifications
5. Indirect Operating costs
   - A. Administrative
   - B. Purchased Services
   - C. Records Maintenance
   - D. Documentation Maintenance

CESSATION COSTS

1. Personnel*
2. Scrapping **
   - A. Facilities
   - B. Equipment
   - C. Computers
   - D. Software
3. Resale Value (-)***
   - A. Facilities
   - B. Equipment
   - C. Computers
   - D. Software

Notes:

* Direct and Indirect labor costs directly identifiable and associated with disposal or replacement of system--includes severance pay.

** All transportation and purchased service costs associated with dismantling and disposal of system.

***Salvage or resale value of system--subtract from cost of new system.

COST BREAKDOWN STRUCTURE

APPENDIX I

RANKING OF EVALUATION CRITERIA

The below listed criteria have been identified as the relevant criteria needed to evaluate the alternative solutions generated in the __________________________________.
(Name of Project)
Your assistance is needed to help rank and/or order these criteria by level of importance. It is requested that you indicate your order of preference as to which criteria you think are most important. As such, please indicate the level of importance by assigning the number one to the most important criteria, the number two to the next most important criteria and so on. After you have completed your ranking, please return this form to _____________________.
(Name)

This questionnaire has been provided to other individuals who have indicated their order of preference. Once all questionnaires have been completed and returned, the data will be collated and the results tabulated. You will be provided with another copy of this questionnaire reflecting these results and asked to review and revise your ordering as you see fit. Hopefully, a general consensus will be derived as to the order of importance of these evaluation cirteria.

Your assistance and cooperation in this effort will be greatly appreciated.

	Evaluation Criteria	Order of Importance	Result of Prior Survey	Revised Order
1.	System Physical Performance Capability of Effectiveness	_____	_____	_____
2.	Total System Cost	_____	_____	_____
3.	System Net Benefit or Savings	_____	_____	_____
4.	Payback Period	_____	_____	_____
5.	Cost Effectiveness	_____	_____	_____
6.	Break-even Analysis Ordering	_____	_____	_____

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